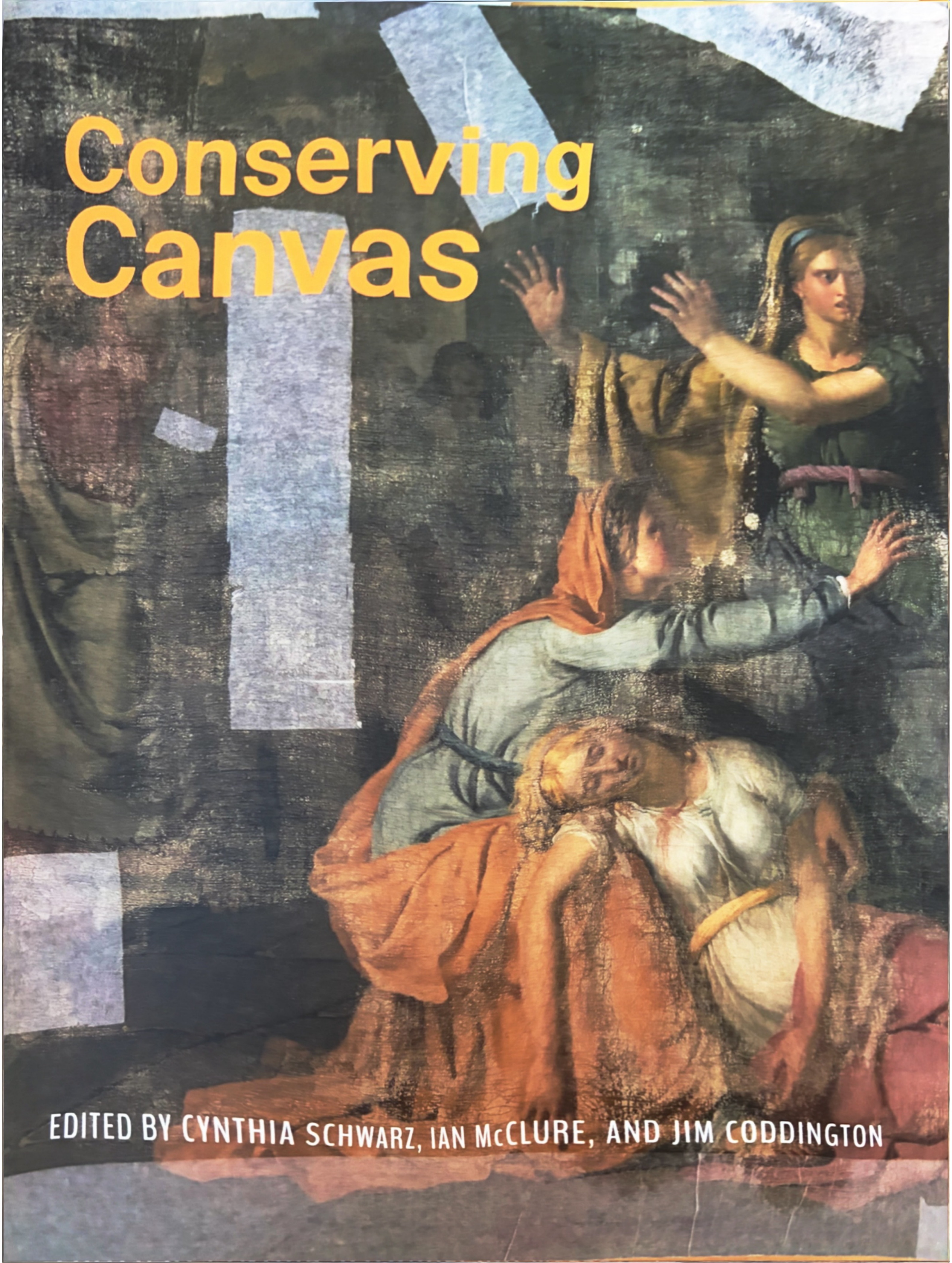
Conserving Canvas



EDITED BY CYNTHIA SCHWARZ, IAN McCLURE, AND JIM CODDINGTON

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Foreword

We are delighted to present the proceedings of the October 2019 international symposium Conserving Canvas. Like the Getty Foundation initiative carrying the same name, the symposium focused on the structural care and conservation of paintings on fabric supports. Organized by the Institute for the Preservation of Cultural Heritage at Yale University, with support from the Yale University Art Gallery and Yale Center for British Art, this momentous event gathered no less than 370 conservators and conservation scientists from around the globe to discuss what was once a heated topic in the field. We are referring to the method of wax-resin lining that previously dominated in the field and was heavily criticized and largely abandoned after the legendary 1974 conference held at the National Maritime Museum in Greenwich, England. At that conference, conservators ushered in an era of new approaches, alternative procedures, and novel synthetic materials. The conference at Yale in 2019 was the first major international gathering on the subject since 1974, allowing specialists to look back on more than forty-five years of practice and take stock of the current state of the field. Thanks to the symposium organizers, professionals from India to Argentina and from Scotland to South Africa met and exchanged ideas, setting new standards for international inclusion in the field. We extend special recognition and thanks to the organizers and advisers who worked hard to make this experience so valuable for so many: Ian McClure, Elizabeth Williams, Cynthia Schwarz, Mikkel Scharff, Christina Young, Alan Phenix, and Jim Coddington.

The care and conservation of paintings on canvas is an ongoing concern for museums around the world. Ever since the 1974 Greenwich conference, many conservators have shied away from structural repairs perceived as too invasive. In many cases this led to unintended consequences, with new generations of conservators possessing little to no practical experience with structural treatments. To address this knowledge gap, in 2018 the Getty Foundation launched the Conserving Canvas grant initiative, which to date has supported twenty-six projects involving conservators and other specialists from more than three dozen countries. The initiative is meant to ensure that conservators remain fully informed about how to preserve these important works of art through support for training activities, scientific research, and information sharing. The Yale conference was a crucial launching pad for this work.

As you will read in this volume, presenters at the Conserving Canvas symposium addressed historical approaches to the treatment of canvas paintings; highlighted current methods, materials, and research; and pointed to the growing challenges associated with the structural conservation of modern and contemporary works. While the record indicates that the atmosphere at the Greenwich conference was quite contentious, the Yale conference could not have been more collegial. Productive dialogue and discussion proved how far the field has come in the last four decades, and the energy and enthusiasm generated among participants was positively electric. Over four days the presenters shared diverse views and approaches, which prompted frank and in-depth conversations. The forty papers and twenty-three posters included in these proceedings reflect that quality and diversity.

The Getty Conservation Institute (GCI) is pleased to sponsor this publication as part of its ongoing service to the international conservation community. Information dissemination is a core activity of the GCI, and the conference papers recorded in this volume are both a touchstone of where the field is today and a vision of where it may be heading next. As such, it forms a valuable reference work for conservators everywhere who are responsible for canvas painting collections.

We are grateful to the volume editors, Cynthia Schwarz, Ian McClure, and Jim Coddington, for their tireless efforts in preparing the manuscript. In Getty Publications, Kara Kirk, Karen Levine, Nola Butler, Greg Albers, and Clare Davis provided invaluable assistance. We thank the book team in Publications—Greg Albers, Rachel Barth, Danielle Brink, Erin Dunigan, and Molly McGeehan—for helping to prepare and shape the final publication. Finally, we are grateful to Leslie Tilley and Dianne Woo for providing careful, thorough editing. This publication and the Conserving Campus symposium represent a renewed openness in the field to a variety of structural interventions, and we thank all our contributors for engaging in productive debates that keep the field moving forward.

Joan Weinstein
Director, Getty Foundation

Timothy P. Whalen
John E. and Louise Bryson Director, Getty Conservation Institute

Introduction

Ian McClure
Jim Coddington
Cynthia Schwarz

The symposium held at Yale University in October 2019 grew out of the Getty Foundation's Conserving Canvas initiative, which, through a combination of practical workshops, publications and research support, and expert meetings, aims to evaluate and foster the structural treatment of paintings on canvas (fig. 0.1). The symposium was planned with the 1974 Greenwich Conference on Comparative Lining Techniques,[1] the last international conference to be held on this subject, very much in mind. At that event, conservators from institutions and in private practice demonstrated a wide range of techniques, both innovative and traditional, and in doing so raised some fundamental questions that are still central to our thinking and decision-making process in planning structural treatments. In the forty-five years since, however, the options for lining and alternatives to lining have expanded. The new options are drawn from a variety of sources: advances in the materials industry, with the production of synthetic adhesives and textiles and the introduction of nanotechnology; new research into the mechanical behavior of laminate structures; and the resourcefulness of conservators who take an innovative approach to their work. Concerns at the forefront of the field in 2019 also included environmental sustainability and a heightened awareness of the benefits of a global perspective on painting conservation.

Conserving Canvas
Symposium
New Haven, CT
October 14-17, 2019
The Getty Foundation
Yale

Figure 0.1 Presenters delivered papers over the course of four days. Seated, from left: Dale Kronkright, Brad Epley, Desirae Dijkema, Mary Piper Hough, Stefan Michalski, Mary Gridley, and Yujin Kim. Image: Mikkel Scharff

The timeliness of the Conserving Canvas initiative and the conference is clear. In the planning stages, it was thought the sessions would be held on Yale's West Campus, where the conservation studios and the Institute for the Preservation of Cultural Heritage are located. High demand quickly dictated a move to the more spacious auditorium at the Yale Art Gallery. The auditorium was filled to capacity with over 370 attendees from more than twenty-five countries, likely the largest gathering of painting conservators ever convened (fig. 0.2). The amount of interest in the topic was also mirrored in the international response, as reflected in the number of papers presented by conservators from more than twenty countries.

Figure 0.2 The Yale Art Gallery auditorium was filled with hundreds of attendees from around the world. Image: Mikkel Scharff

The impact of the postprints of the 1974 conference was even greater than that of the conference itself, as they not only presented to a much wider audience the different approaches introduced there but also questioned previously held assumptions. While the conference provided the opportunity for conservators to compare lining techniques, with a focus on practical workshops, the necessity of lining as a preservation measure was ultimately called into question. For many, the most perceptive and significant paper was the opening presentation by Westby Percival-Prescott, "The Lining Cycle," in which he demonstrated how artists' techniques of a certain period affected the response of those paintings to particular lining practices of the time, usually evident many years later when those paintings were deemed to require lining.[2] Percival-Prescott's paper, after reviewing different lining techniques, called for research into methods that might prevent the necessity of lining (see Stoner in this publication). In effect, a call for historical research and a minimalist approach was made.

With this context in mind, the call for papers for this symposium, made in September 2018, announced, "The symposium will address historical approaches to and theories of the structural conservation of canvas paintings; current methods, materials and research, both practical and scientific; and the challenges facing the structural conservation of modern and contemporary works." This reflected, in the view of the Advisory Committee,[3] developments and concerns in the structural treatment of works on canvas today. The response to the call for papers was much larger than expected, and the proposals submitted guided the committee to choose the sections laid out in these postprints.

While Percival-Prescott's paper was unique in providing a historical review in 1974, at the 2019 symposium historical research played a very significant role. The recent research into contemporary documentary sources, discussed in contributions by Angela Cerasuolo, Matteo Rossi-Doria, and Ana Calvo et al., attest to considered practices dating back to the eighteenth century and earlier. In many cases, written sources can be linked to surviving treatments, often demonstrating the unexpected longevity of linings carried out with natural materials. A strong case is made for the use of natural materials—both for their low toxicity and their performance over time. On the other hand, assumptions about the stabilizing hydrophobic attributes of wax-resin treatments were called into question by new research, as can be seen, for example, in the work by Emilie Froment. A divide on seeking flexibility (as in mist-lining) or rigidity (as demonstrated in Lynne Harrison's paper) in a lining or lining system emerged, which also represented the trends of research on lining procedures and the mechanical behavior of the composite structure of paintings since the Greenwich conference. The fact that many of the practical and philosophical divides in structural practices still fall along geographic lines speaks to the sustained, deep roots in historical treatment practices.

Another theme that emerged at the Yale conference was an emphasis on the history and treatment of collections as a whole, as well as forward-looking preventive care of collections. Here, too, the role of past and ongoing research was evident, although perhaps not always carried over into practice. Increased levels of documentation also allow for the examination and analysis of more data, mostly focused on collections and their treatment histories. The greater attention to documentation has enabled reviews of institutional practice—which, when the data are extensive enough, reveals trends, as evidenced in the contributions by Nicola Costaras and Lauren Bradley and Josh Summer. A series of case studies covered the treatment of works large and small and highlighted the significant attention paid to local interventions, which demonstrate conservation's continuing ability to adopt and adapt existing techniques and equipment from other fields, such as textile conservation, imaging technology, and mechanical engineering. Papers included research using samples of significant natural aging and showed the ongoing embrace of new materials—both from other fields and those specifically developed for conservation. The audience was introduced to Hannah Flock et al.'s "Winnie" for the application of glue in tear mends, for example, as well as the adhesive meshes developed by Mona Konietzny et al.

Threaded through all of these topics was the ongoing question of definitions, of finding a common vocabulary to describe—with as much precision and accuracy as possible—what conservators see and do. This is especially critical in order to exchange philosophies, methodologies, and techniques with an international community that has grown out of a variety of historical traditions and practice in vastly different climates. To that end, we have included a glossary based on the one published in the 1974 preprints. Terms no longer in use have been deleted and terms that have become current have been added. It is our hope that this revised glossary reflects developments since 1974 while also attempting to define terms that can be used universally. Finally, around the margins but clearly moving to a central position is the question of sustainability in all its various forms. Indeed, here is a term in need of definition and common understanding.

One part of the conference that is not available to the reader of these proceedings is the day devoted to practical demonstrations—"sandbox sessions"—that provided the opportunity for experiential learning (fig. 0.3). Expert contributors led sessions on historical reconstructions, innovative tools and equipment, hands-on mechanical demonstrations, and localized tear mending. It is the continued refinement of established practice, as well as development of new, more effective practices, that these sessions represent, and to which we believe these proceedings will be an ongoing contribution.

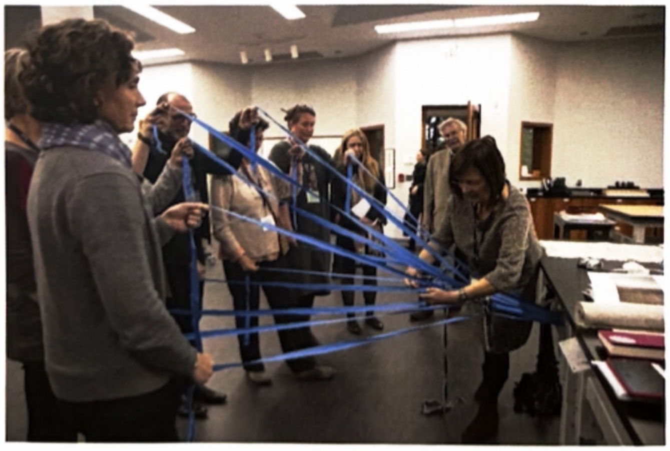

Figure 0.3 Conference participants took part in "sandbox sessions" led by experts giving practical demonstrations. Here, author Helena Loermans leads a workshop on reconstructing historical fabric weave patterns. Image: Mikkel Scharff

None of this would have been possible without the support of a large network of our generous, capable colleagues. First, thanks are owed to the rest of the symposium Advisory Committee: Alan Phenix, Mikkel Scharff, Antoine Wilmering, and Christina Young. At Getty, thanks also to Joan Weinstein and Allison Reilly. At Yale, thanks go to Stephanie Wiles; Henry J. Heinz II, director of the Yale University Art Gallery; and Courtney Martin, director of the Yale Center for British Art, for their support, contribution of space and resources, and hospitality shown to the participants. The conference would not have been possible without the ongoing efforts of Laurie Batza, Beth Bolen, and Elizabeth Williams at the Yale Institute for the Preservation of Cultural Heritage. Also, thanks to the Yale Conferences and Events staff, especially Shannon LeGault, who arranged two meals a day and warm welcomes for our 370 participants. The Avangrid Foundation provided critical funding support for presenters and attendees from Spain, and our special thanks go to Nicole Licata Grant. The program books were designed by Stephanie Bedoya with the assistance of Yale University Art Gallery designer Chris Sleboda, who also designed the tote bags for the participants. Advertising support from Willard Conservation Products, Everett Fine Art, and Getty Publications made the program books possible. At the Yale University Art Gallery, thanks are owed to Molleen Theodore, Liz Harnett, Mark Paturzo, and Roksana Filipowska. Many Yale University conservators, conservation fellows, and interns contributed to the success of the symposium, from hosting guests and providing directions to assisting in sandbox sessions and hanging posters, and too many other supportive roles to mention. Our deep thanks for this to Irma Passeri, Kelsey Wingel, Mark Aronson, Jessica David, Anne Gunnison, Olav Bjornerud, and Beth Godcher. We are also deeply grateful to Rachel Barth, Leslie Tilley, and Dianne Woo for their support, dedication, and patience as they edited and proofed sixty-three papers. We hope that this publication will be of great value to the international conservation community for years to come.

NOTES

1. The postprints were published as Villers 2003b.
2. Many of these effects changed the appearance of the paintings. These changes to the structure, topography, and other attributes of the painting have been described in various ways in the conservation literature. Most importantly, though, a consensus emerged that these changes compromised the aesthetic integrity of the painting, bringing aesthetic discussions of the surfaces of paintings to the fore as well as discussion of technical matters.
3. The Advisory Committee consisted of Jim Coddington, Ian McClure, Alan Phenix, Mikkel Scharff, Cynthia Schwarz, Antoine Wilmering, and Christina Young.

I

History, Principles, and Theory

1

Understanding Structure, Changing Practice

Stephen Hackney, Head of Conservation Science (retired), Tate, London

In the latter part of the twentieth century, conservators questioned the practice of lining paintings on canvas. This inspired fundamental scientific studies of the structure, material, and aging of paintings. The implications of mechanical and chemical aging can now be better predicted. This knowledge has provided conservators with a wide variety of alternative treatments, and it supports the concept of collections care.

◆ ◆ ◆

STRUCTURAL CONSERVATION

By addressing the structure of a painting, we are forced to consider not only the image intended by the artist but also the artwork's physical nature and history. A stretched canvas is a subtle and delicate construction devised for both stability and lightness, but if the structure is damaged or failing, this creates risks for both the appearance and purpose of a painting.

As any artifact ages and deteriorates, it eventually reaches a point when its appearance and functions are judged to be no longer acceptable. Some of these changes demand action in order to preserve the artifact's use and prevent further decay. Some changes are not reversible—for instance, cracks, which indicate fragility and may cause a disturbing interference with an image. Yet, in a painting, cracks are also viewed as a sign of authenticity.

Structural conservation of a canvas painting can be a more profound intervention than cleaning or varnish removal, and each intervention presents fundamental aesthetic challenges for the paint surface and ethical doubts for the concept of reversibility. A structural treatment may be applied to an entire painting, perhaps in a single, rapid operation. Like other aspects of conservation, such a treatment requires considerable judgment and skill, and success is often determined by the treatment's invisibility.

Fifty years ago, a traditional lining method was considered a normal component of any conservation treatment. The lining used was defined by the choice of adhesive, and these materials had a surprisingly wide range of properties, from water based to water repellent. The goal of lining was to turn a fragile canvas painting into one that was much more resilient, but the means and the outcome were not well defined. The dangers in lining were recognized, however, and it was normally carried out by skilled and experienced professionals. But attempts were also made to automate and deskill the process by using hot tables and vacuum pressure.

For the student, there was little published information except for some early discussions on reservations about glue lining, the justification for introducing wax-resin adhesives, and designs for hot tables (Ruhemann 1953; Straub and Rees Jones 1955). From this background, Westby Percival-Prescott conceived the Conference on Comparative Lining Techniques, held in Greenwich (London) in 1974. This ambitious project brought together experts from various backgrounds, but it succeeded in uncovering much confusion of purpose and also a genuine desire to improve the situation (Percival-Prescott 2003b). Traditional methods were described by practitioners, and several research projects investigating alternative adhesives and lining methods were presented. A wide variety of conservation aims emerged, from restoring the original appearance of a painting to accepting its existing condition (Mehra 2003). For the first time, the advantages and disadvantages of all materials and methods were openly debated, including wax-lining methods (Berger and Zeliger 2003; Cummings and Hedley 2003).

During a period when lining was widely, uncritically accepted, most practitioners had honed their skills in a narrow lining specialty based on one specific adhesive and had a limited range of experience. The establishment of conservation training courses with academic aspirations has now largely replaced the former apprenticeship training, which passed on the strengths and skills of existing practices but had no mechanism to compare or improve on them. Formal training has provided an impetus for conservation science, and the study of conservation methods has influenced the materials and practice of conservators and even some artists.

SCIENTIFIC RESEARCH

After Greenwich, it was clear that an understanding of the structure and mechanisms of stretched canvas paintings was needed. This has since been achieved by a number of researchers, beginning with Marion Mecklenburg and his systematic studies that provided measurements of painting materials under tension and different RH conditions, identifying the high tension in glue films and grounds at low humidity. Measurements of breaking strains of oil paint films led to an explanation of the observed cracking of canvas paintings (fig. 1.1).

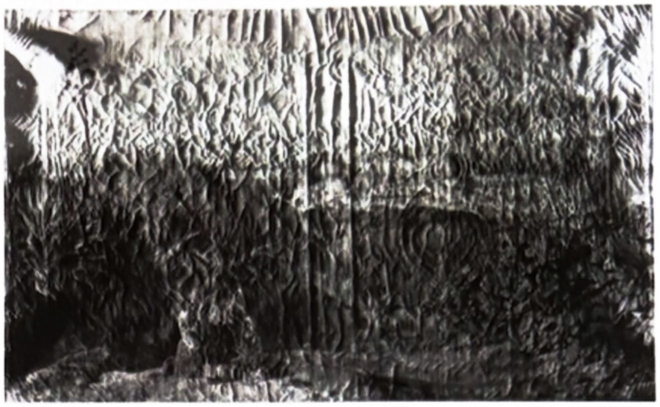

Figure 1.1 Edward Lear, *View of Reggio and the Straits of Messina*, 1852. Oil on canvas, 51.4 × 81.2 cm (20 1/4 × 32 in.). Typical raised crack pattern, impact cracks, and canvas corner undulation in raking light. Image: Tate

The response of paintings to moisture had been a particular concern since the nineteenth century. Mecklenburg's plot of tension against RH for all the materials on a stretched and primed canvas was a major advance (Mecklenburg 1982; Mecklenburg and Tumosa 1991a). Gerry Hedley explained the mechanism of canvas shrinking when exposed to water or RH approaching 100%. He also saw the effect of initial weave crimp transfer from warp to weft (Hedley 1993; Hedley and Odlyha 1993). The differing influence of pigments on the drying (curing) of linseed oil explained why the application of moisture and pressure is not enough to flatten most mature lead white paints. Temperature response of paintings was also investigated (Michalski 1991). Cracking of otherwise flexible acrylic paintings at extremely low temperatures was at first surprising. The concept of glass transition temperature (Tg) clarified why familiar flexible materials became brittle at these low temperatures.

Long-term mechanical behavior, such as relaxation and creep, has also been measured, providing useful predictions of future behavior. It took sixteen years to collect the data presented at the Canadian Conservation Institute, which show the relaxation (loss of tension) of stretched canvas paintings and linings over that period of time, plotted on a logarithmic time axis (fig. 1.2). Such data are critical when deciding on the best choice of adhesive and lining material.

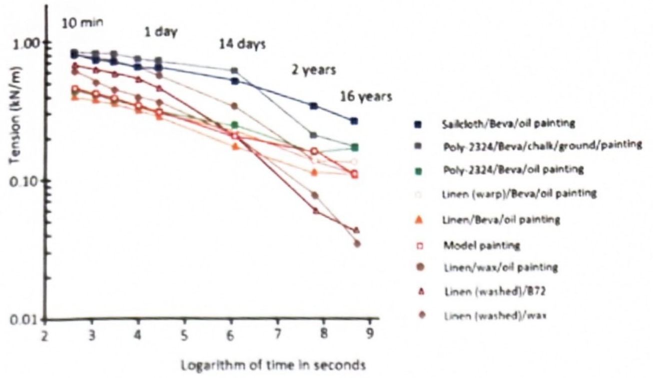

Figure 1.2 Long-term relaxation for several canvases and linings plotted logarithmically against time (Daly Hartin et al. 2011). Image: Stephen Hackney

The use of biaxial stretching, first proposed by Berger (Berger and Russell 2000), and electronic speckle pattern interferometry (ESPI) for strain measurement (fig. 1.3) enabled Young and Hibberd to look in further detail at conservation issues and lining practices, such as the strain associated with stretcher attachments (Young and Hibberd 1999; Young and Hibberd 2000). The complex structure of stretched canvas is now understood in sufficient detail to consider computer modeling of the mechanical properties of both paintings and linings. It also offers the opportunity to study in more detail the effects of minimal treatments on more contemporary paintings (Hagan et al. 2007; Hagan et al. 2011b). Temporary solutions and physical protection may prove to be our best options, but many have not yet been fully assessed objectively.

CONSERVATION PRACTICE

Transferring research results into conservation practice on historical objects involves special problems. Understanding materials in a pristine state is not enough to predict the behavior of deteriorated old paintings (Ackroyd 2002; Hackney 2004b; Phenix 1995; Reeve 1984; Scharff 2012). Since an assessment of physical condition and appropriate treatment requires such knowledge, measuring slow processes such as "natural" aging is increasingly necessary in order to make reliable long-term decisions.

Progress in devising and applying new conservation treatments is made difficult because at some stage practical experience can be gained only by working directly on unique and valuable original aged material (fig. 1.4). It might be argued that this amounts to carrying out scientific experiments lacking a control. As a consequence, we can choose our treatment method but cannot be sure it was the best of several possible options.

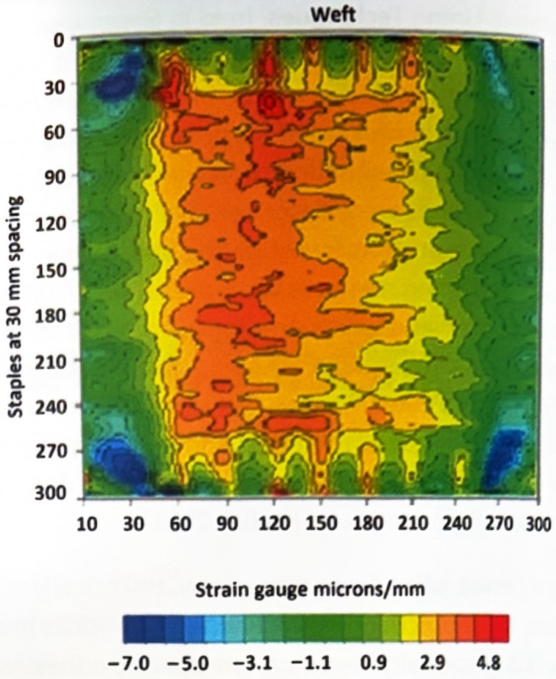

Figure 1.3 Strain variations near the canvas edges associated with the use of tacks for attachment to the stretcher (Young and Hibberd 1999). Image: Stephen Hackney

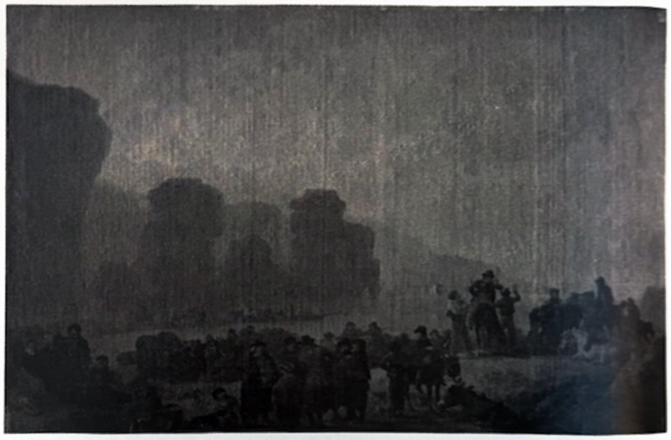

Figure 1.4 Julius Caesar Ibbetson, *Smugglers on the Irish Coast*, 1808. Oil paint on canvas, 54.6 × 85.1 cm (21 1/2 × 32 in.). Glue-lined oil painting, possibly including megilp chosen by the artist for its fluidity (Ibbetson 1803). The raking light reveals flattened impasto and weave emphasis from glue lining. Image: Tate

In the United Kingdom, original nineteenth-century loose linings have provided a limited source of acceptable experimental material, but such material has still not been replicated reliably in all its aspects by artificial aging methods.

For the conservator concerned with historical paintings, it is important to be aware of artists' changing methods, materials, and intentions. There is much detail, accumulated from the examination of examples of painting practice, to inform the conservator of the likely behavior of a specific painting to be treated. For the period from the latter part of the nineteenth century until the present, artists were less bound by academy controls; their aims became more adventurous, and their materials and methods expanded. As paintings from this period increasingly demand attention and treatment, the conservator is presented with a variety of interesting new problems and conflicts, many of which have already contributed to modified conservation practice for works on canvas, currently leading to a more preventive approach. The demands of much recently created art provide a challenge that requires radical solutions, and they are pointing to new directions in conservation of both contemporary and traditional art (Heiber 2003).

Some developments of lining processes using new materials, such as sailcloth fabric (Hedley and Villers 1982) and Beva 371 adhesive (Berger 1975), have so far survived the test of time. Exploring the properties and stability of possible alternative conservation structural materials is a major undertaking, made more difficult by the risk that material manufacturers may discontinue their supply. Economics also conspire to deter time-consuming structural treatments. As a consequence, for many contemporary paintings, restoration often challenges existing experience and costs much more than preventing damage (fig. 1.5).

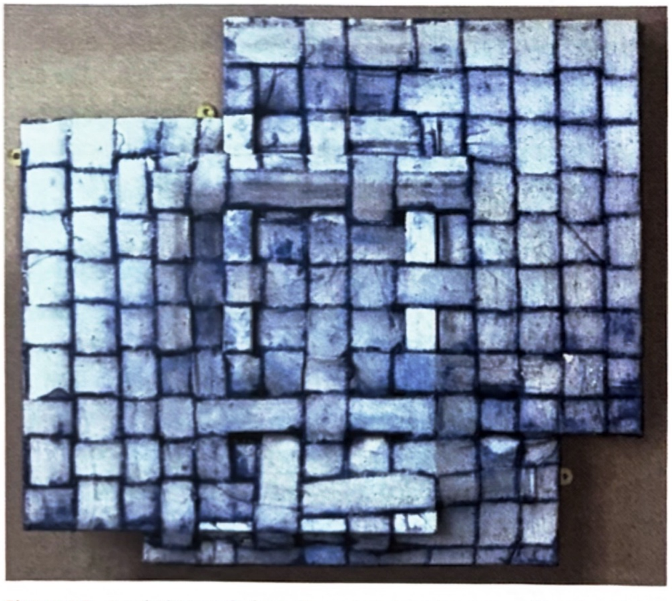

Figure 1.5 A painting made from three stretchers interwoven by strips of canvas, which presents a structural conservation challenge. Stephen Buckley, *Nice*, 1972. Acrylic on canvas, 81 × 90.2 × 5.1 cm (32 × 35 1/2 × 2 in.). Tate, London. Image: © Stephen Buckley / Photo: Tate

COLLECTIONS CARE

Given the many unavoidable problems encountered in conservation treatments, protecting canvases from physical and chemical deterioration is now considered a priority in many museums. For the conservator, it has always been difficult to predict the range of conditions to which a painting has been and could be exposed. The environment that a specific painting is likely to encounter remains uncertain, even within museums. Increasingly, we ask what are the true risks for paintings on canvas, and how should we decide when intervention is necessary?

Improvements in the environment of modern museums (controlled and filtered air-conditioning, UV filtration); careful handling and operating procedures; and protection during transport and handling have all contributed to more reliable conditions. Defining exact relative humidity/temperature (RH/T) conditions is virtually impossible, but the absence of identifiable damage that can be directly attributed to current museum conditions is a positive indicator. However, more recently, an open-ended commitment to long-term protection by air-conditioning has been challenged as expensive and unsustainable in energy terms.

In the past, the risks of travel were unpredictable and thought to be large. Conservators were therefore obliged to reinforce a painting's structure to the best of their ability. With increasing loan and exhibition programs and major blockbuster exhibitions, this has become an international problem. The transport environment has now been examined in terms of shock, vibration, moisture content, and temperature along with their consequences for paintings in transit. Criteria for behavior and designs for packing cases to minimize exposure to risks have become established. An interesting observation from the Art in Transit research group was that, by using reliable methods and tight procedures, transport risks could be reduced below those of handling within a museum (Mecklenburg 1991).

By introducing consistent procedures for the physical protection of works of art, it is easier to avoid much accidental damage and unnecessary early deterioration. Successful collections care procedures have together made the idea that lining is a requirement much less persuasive and forced us to be more precise about its purpose.

CHEMICAL AGING PROCESSES

For the long-term survival of paintings, the less dramatic yet equally important chemical degradation of canvas, size, ground, and paint needs to be considered. However, the exact condition of aged canvases and their continuing rate of decay cannot be known in sufficient detail and are not readily captured in most risk analysis, which is currently concerned with shorter term, mainly physical activity.

The slow reactions of oxidation and hydrolysis that take place in degrading cellulose and oil paint are the main reasons that painting materials become fragile. What were originally stable structures no longer perform their design function, and physical damage often follows. Air pollution and light contribute to this deterioration, involving chemical interactions between canvas and its immediate environment. They play a subtle, perhaps unstoppable role in aging.

Between 1900 and 1960, air pollution was at its worst in many countries. Most museums were not air-conditioned, and until about 1990 concentrations of particulates and the strong acidic gas sulfur dioxide remained unacceptably high. In the last hundred years or so, exposed canvas has adsorbed sulfur dioxide from air pollution; the sulfur dioxide then reacts with the cellulose in the canvas. The products are not volatile and remain in the canvas, facilitating hydrolysis reactions. All acidity, whether from external and internal pollution or simply from oxidation, cause measurable weakening and embrittlement of the canvas (fig. 1.6).

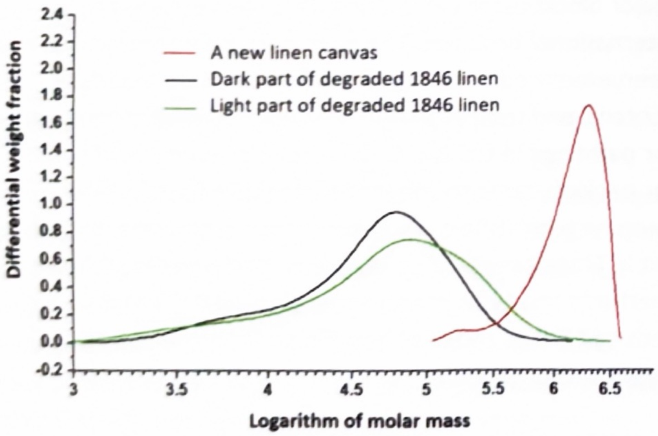

Figure 1.6 Plot of molar mass distribution. A new canvas on the right with a range of very high molecular weights compared with two samples of a J. M. W. Turner loose-lining canvas (painting dated 1846). The peaks (modes) for the Turner canvas are at much less molar mass and there is a greater spread of molar masses than for the new canvas, indicating that the long cellulose molecules have been cleaved at many points. Also, the darker exposed parts are more degraded than the lighter parts behind the stretcher. Canvas samples analyzed at BOKU Vienna during the EU MEMORI project (Jeong et al. 2013). Image: Myung-Joon Jeong, Manuel Becker, Antje Potthast, Susana López-Aparicio, and Stephen Hackney

Efflorescence can occur on the surface of oil paintings, especially unvarnished ones, and on glazed works it is sometimes transferred onto the glass. This deposit has been analyzed as fatty acids (Williams 1989), which must have been released from the oil paint. The hydrolysis of oils is well known, and migration of its reaction products within dried oil paint films explains efflorescence.

There has been a major advance in understanding the degradation of oil paint and how it changes the paint's optical performance and our perception of a painted image (Boon, van der Weerd, and Keune 2002; Keune 2005). We are all familiar with the increase in transparency of oil paintings and grounds. The impregnation and lining of paintings with thin grounds can also cause increases in transparency, especially when wax resin has been used (Bomford and Staniforth 1981). We now know that old paint films form an ionomeric structure that continues to deteriorate by hydrolysis and oxidation. Saponification reactions of free acids with alkaline or basic metals present in finer pigments, such as calcium, magnesium, lead, and zinc, can dissolve pigments into the paint. Removal of these light-dispersing fine pigments causes the paint to increase in transparency.

I recently conducted experiments involving mixing acid-base titration indicators into various fresh white oil paints and then painting them out. In a few minutes, the pH 4, 4.1, and 4.7 indicators began to change color, but the pH 3.3 and 3.7 indicators remained unchanged for months. For comparison, samples were removed and exposed to ammonia vapor to return them to their initial color (for a short time). Similar control samples in artists acrylic paint did not change color at all. This demonstrates that oil paint becomes acidic within a short period of time (Hackney 2020).

The acidic nature of dried oil paint is the reason why artists do not paint directly on canvas but instead protect it with a coat of glue size. The application of an oil ground or paint on top of this water-soluble size layer produces many of the structural and mechanical problems that we have to deal with. A hot glue size will engulf the canvas, but when applied cold it can accumulate on the canvas surface (Morgan et al. 2012). If and when a glue size cracks, its barrier properties are reduced and volatile breakdown products (VOCs) may reach the canvas.

Similarly, if we add a consolidating or lining adhesive that can become acidic on oxidation, the canvas will be exposed to more rapid deterioration. These arguments suggest more research is needed into both conservation adhesives and ways of achieving adequate deacidification of canvas (Hackney, Townsend, and Wyplosz 1996; Ryder 1986).

Enclosure on display or in storage to reduce moisture exchange and deposition of external pollution, such as nitrogen dioxide and particulates, is an important conservation measure (McClure 2012) and a more sustainable alternative to air-conditioning, but measurements within enclosures demonstrate that we have to be careful in its use (fig. 1.7).

The concentration in air is not in itself a measure of reaction rate, but it shows that more molecules are available to react. Below 0.5 AER (air exchange rate), the rate of off-gassing of acetic acid, both from the packaging and (some) from the object, exceeds the combined leakage rate and rate of deposition or reaction, the latter being slow processes. When reactive molecules collide, only a small proportion reacts, but in these circumstances trapped pollution molecules can collide many times and will eventually react. The introduction of sacrificial adsorbers or reactants might therefore be useful, provided they are placed close to the object.

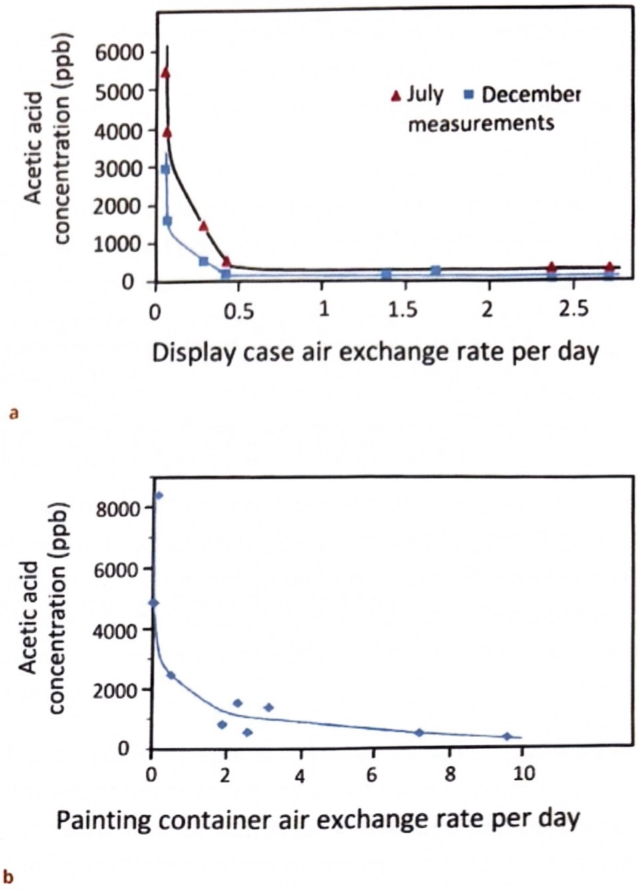

Figure 1.7 Two separate studies showing that below 0.5–1.0 air exchanges per day, the air concentration of internally generated volatile pollution soars. (a) Large-volume display cases (Thickett et al. 2007). (b) Various narrow painting frames and cases (Grøntoft et al. 2011). See Hackney 2016. Image: Stephen Hackney

CONCLUSION

There is still plenty of work to be done, but at last we know that we can build on a growing body of knowledge. We still need to turn this knowledge resource into genuine expertise and practical conservation experience. We also need to embed in our minds the concept of preventing deterioration, which will be appreciated by future practitioners who will still be addressing the same ethical issues. The Conserving Canvas symposium provided a useful forum to take stock of recent progress and to assess its contribution to the development of an agreed way forward.

2

Applied Mechanics and the Structural Treatment of Paintings on Canvas

Eric Hagan, Senior Conservation Scientist, Canadian Conservation Institute

Paintings on canvas are composite structures with mechanical properties that are difficult to characterize due to many complicated issues: the wide range of artists materials and techniques, which vary by region and time; the changing properties of materials with age and environmental exposure; and the addition of conservation treatments. Paintings are also composed of viscoelastic materials, which means that properties such as stiffness and extensibility are time and temperature dependent. This large matrix of variables makes it impossible to characterize the behavior of all paintings in the same way that an engineer might describe a distinct structure under a narrow window of conditions and boundary constraints. Valuable information is instead derived from materials testing of representative samples, development of simplified models, and expert knowledge from past successes and failures. As a result of the complexity, heuristics is often applied in conservation treatments. This paper provides a generalized overview of the mechanical behavior of paintings in tension and describes trends that help to refine the heuristics approach. The discussion is presented in the context of a viscoelastic (time-dependent) material model rather than elastic-plastic in order to highlight key concepts.

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INTRODUCTION

Those studying the mechanical behavior of artists paints and painting structures will likely begin with the general elastic-plastic stress-strain relationships often discussed in introductory engineering texts. A classic diagram will label elastic modulus, yield point, ultimate tensile strength, and failure strain from a simple tensile test. The concepts then become incredibly complex when delving deeper into the response of polymeric materials under varying conditions. This is particularly true for artists paints when considering the influence of temperature, rate of deformation, moisture content, additives to the polymer matrix, and many other factors. To accurately characterize the small-strain behavior of paint films over a wide range of conditions, it often necessary to consider a linear viscoelastic material model (Ferry 1980). Describing the large-strain response may require adding hyperelasticity (Treloar 1975) for an extension to a nonlinear viscoelastic material (Christensen 1982). An example of this approach was developed for acrylic (latex) artists paints containing titanium dioxide (Hagan et al. 2009), which provided parameters for finite element analysis in software such as Abaqus. Calibrating such a model—even for one material—is no easy task. It involves many tests and numerical iteration to solve the best fit parameters to experimental data, and simplifying assumptions still remain.

When pigment particles are included in the polymer matrix of a paint film, the material becomes a particle-filled composite with a viscoelastic matrix. Stiffness enhancement as a function of particle volume concentration is described in many micromechanics models; however, most give little consideration to geometry effects. The Mori-Tanaka theory is particularly useful since it considers the influence of particle shape and orientation in addition to volume fraction (Tandon and Weng 1986). Clements and Mas extended this theory from an elastic to linear viscoelastic matrix for small-strain modeling (Clements and Mas 2001). The effects of particle shape and concentration were highlighted for artists acrylic paints using kaolin, calcium carbonate (aragonite), and titanium dioxide as an inorganic phase in a recent study (Hagan et al. 2011a). From this research, it is easy to imagine that the properties of a paint layer may be different along a brushstroke relative to the transverse direction, due to the alignment of pigment particles with an aspect ratio not equal to 1. The composite structure of a painting on canvas adds further complexity given the layering of different materials and boundary conditions at the stretcher. Common treatment approaches, such as linings, add further variables.

It is impractical to think that we can precisely understand the mechanical behavior of paintings with so many influencing factors, which additionally include chemical effects of the aging process, the physical aging of polymers (Struik 1980), load cycling, fracture, and delamination (Tantideeravit et al. 2013). While researchers work to better understand and model these materials for risk analysis, it is important to use the best information available in a heuristic approach to resolving practical problems of the moment. Waller and Michalski emphasized the value of heuristics in preventative conservation:

> A fully rational approach would require that all possibly relevant information be obtained and used in arriving at a decision or evaluation. The cost of—and time required for—a fully rational decision is infinite. Instead, a conservator evaluates, using heuristics (simple rules of thumb or intuition), whether there is an advantage in seeking more information before deciding whether a particular issue, such as a risk to a collection, is significant or not. (Waller and Michalski 2004, 6)

In "Toward a Definition of the Engineering Method," Koen defines *heuristics* as "anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification and fallible. It is anything that is used to guide, discover and reveal a possible, but not necessarily, correct way to solve a problem" (Koen 1988, 308). An important comparison is given to the different approaches of the scientific and engineering methods. Koen also states that "the engineering method is the use of engineering heuristics to cause the best change in a poorly understood situation within the available resources" (Koen 1988, 308). There is clearly a similarity between the work of a heritage conservation professional and an engineer, with respect to problem-solving under challenging circumstances with many unknowns.

A pertinent example of the engineering method is found in the renowned body of research by Mecklenburg related to the mechanics of artists materials and the effects of the museum environment. In the proceedings of the 1991 Art in Transit meeting, Mecklenburg and Tumosa present findings that highlight the tensile properties of artists paints as a function of strain rate (Mecklenburg and Tumosa 1991a). In contrast, subsequent research gives descriptions of material behavior that use an elastic-plastic (time-independent) model (Mecklenburg 2005). Strain rate is fixed to a constant value in mechanical tests to generate timely and practical information on the effects of the museum environment without the burden of viscoelastic theory.

The aim of this paper is to revisit some key concepts in the time-dependent mechanical behavior of paintings, as a supplement to fundamental knowledge of mechanics. The concepts relate to many of the treatment methods used in practice where material behavior is altered by changing different parameters. Detailed theory and test results are presented elsewhere; therefore, the focus is on generalized trends for clarity. A brief review of lining effects on stiffness and stress relaxation of painting is also provided to complement a more in-depth discussion regarding the Canadian Conservation Institute (CCI) Lining Project (Daly Hartin et al. 2011).

MECHANICAL RESPONSE OF PAINTINGS IN TENSION

Stress-Strain Curves

A stress-strain curve is derived from a simple tensile test, and it is often used to characterize the mechanical properties of painting materials. Force and displacement measurements are converted to stress and strain in order to remove the effects of sample geometry. The initial slope of a stress-strain curve in uniaxial tension is a measure of stiffness called the modulus of elasticity, E, or Young's modulus. Experiments in shear mode define the shear modulus, while hydrostatic pressure gives the bulk modulus. For a viscoelastic material, these elastic moduli are time dependent, and the stress-strain relationship is nonlinear due to polymer relaxation during the test. Figure 2.1 shows stress-strain curves from a series of tensile tests performed on free films of an artists oil paint. The results highlight that the modulus decreases with higher temperature and reduced rate of deformation, while the failure strain increases. Despite this trend, there is no simple relationship between stiffness and failure strain for materials in general. A material may be stiff and brittle or compliant and brittle.

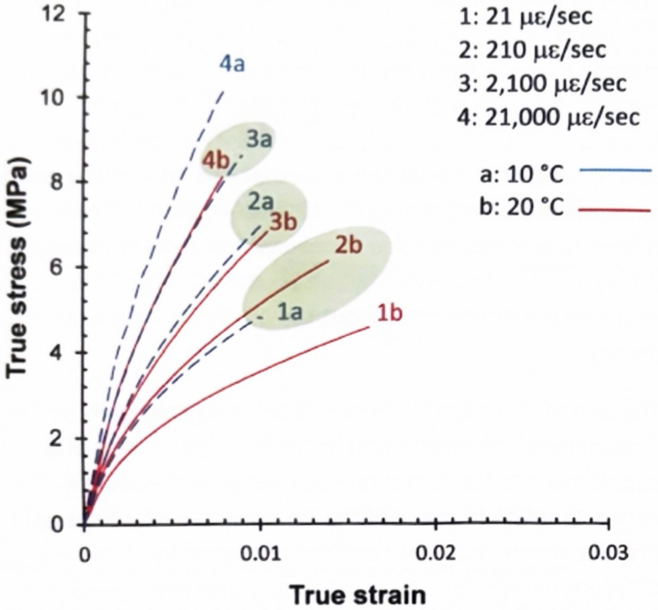

Figure 2.1 Stress-strain curves for a titanium white artists oil paint at different strain rates and temperatures in uniaxial tension. Image: © Government of Canada, Canadian Conservation Institute

Figure 2.2 illustrates the results of a tensile test with the time dimension added. The first graph (fig. 2.2a) shows the strain history as millistrain versus time, and indicates that the strain rate, R, is constant during the constant speed test due to the low failure strain. At higher strains, the strain rate would measurably decrease during a constant speed test due to the changing length of the sample. The second graph (fig. 2.2b) gives stress versus time, and the third (fig. 2.2c) presents a stress-strain curve. The latter shows a secant modulus, E_s (at strain $\varepsilon = 0.005$), and the strain at failure ε_f. Secant modulus can be a useful measure of stiffness due to nonlinearity caused by relaxation during the tensile test.

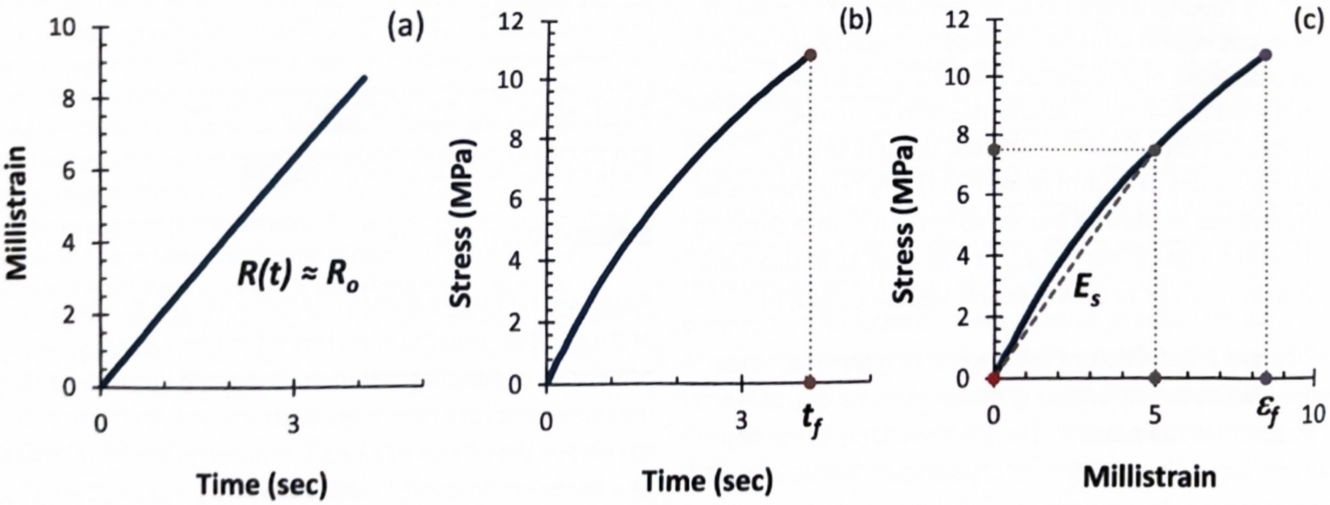

Figure 2.2 Tensile test data for a nine-year-old sample of Winsor & Newton Foundation White at 20°C, 50% RH, and a rate of 2100 με/sec. Image: © Government of Canada, Canadian Conservation Institute

Stress Relaxation

A relaxation test is another useful experiment for studying time-dependent material properties, and it is particularly relevant to canvas-supported paintings. Figure 2.3 illustrates the different parameters in a stress-relaxation test performed on a Winsor and Newton Foundation White film. The first graph (fig. 2.3a) shows the strain history as an initial loading ramp, followed by constant strain during measurement of stress relaxation. The second (fig. 2.3b) shows the loading ramp on a stress-strain curve, and a vertical drop in stress during the constant strain segment. Figure 2.3c gives the stress relaxation process on a plot of stress versus time, where it appears that stress is approaching equilibration after a sharp initial drop. The final plot (fig. 2.3d) shows the same data on a log-log scale and highlights that the sample is still relaxing. The results also show similar findings for a repeat test that was performed on the same sample after a twenty-four-hour recovery period. During cyclic load testing on viscoelastic materials, it is important to consider strain history and its effects on repeated measurements.

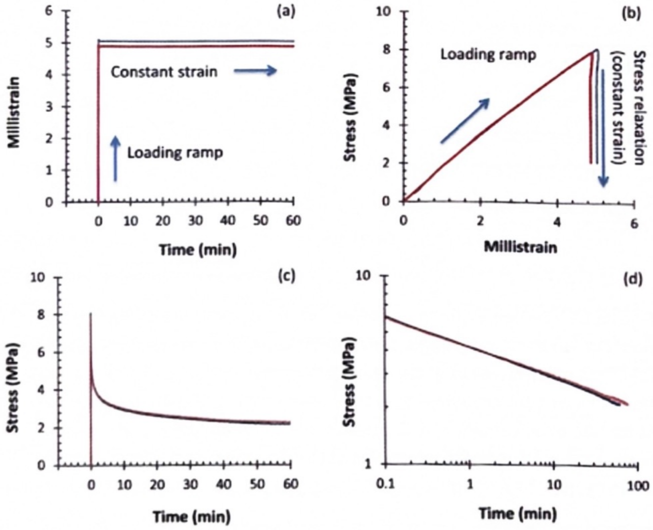

Figure 2.3 Stress-relaxation test performed on a nine-year-old sample of Winsor & Newton Foundation White: (a) strain history, (b) stress-strain curve, (c) stress relaxation on a linear scale, (d) stress relaxation on a logarithmic scale. The red lines show a repeat test on the same sample after unloading and a twenty-four-hour recovery period. Image: © Government of Canada, Canadian Conservation Institute

The stress-relaxation test method outlined in figure 2.4 is the approach used in the CCI Lining Project to investigate the effects of different lining treatments for paintings on canvas (Michalski and Daly Hartin 1996). From recent work, figure 2.4 shows a plot of tension (kN/m) versus time after a fixed strain was applied to each sample (Daly Hartin et al. 2011). The initial sharp spike is caused by the rapid initial strain (see figs. 2.3b, 2.3c), which is followed by a quick decay in tension due to stress relaxation. The model painting with a linen lining shows no difference from the model painting (unlined) over the measurement time scale. The sailcloth lining causes a uniform vertical shift in tension due to the stiffness of the fabric, which is constant over the sixty-hour period. An advantage of the sailcloth lining is that its stiffness allows for a stable increase in tension, with less strain imposed on the painting. In fact, the strain could be reduced to roughly half and still maintain a similar tension to the model painting in the experimental time scale. The wax-resin lining also shows a strong vertical shift due to the wax stiffness; however, it also exhibits relaxation characteristics.

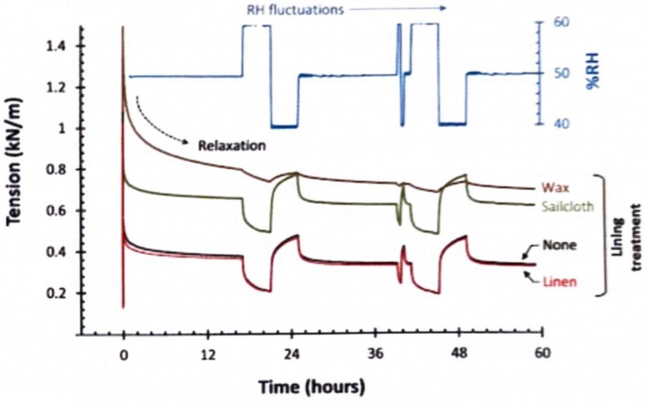

Figure 2.4 Stress relaxation at 1 millistrain for a prepared model oil painting with different lining treatments. Image: © Government of Canada, Canadian Conservation Institute

The addition of RH fluctuations in figure 2.4 highlights some further trends in the lined painting response. Sailcloth and linen have no effect on the response of the painting, since the linings do not constrain the paint layers in the direction of applied tension—that is, painting and lining are free to shift across one another. In contrast, the wax-lining impregnates the canvas and constrains the paint layers from shrinking or swelling due to contact with the supporting layers of the painting. The paint layers still respond to RH fluctuations; however, the wax adds surface constraint that prevents movement and a subsequent change in tension measured at the ends of the sample. A more in-depth discussion of the CCI Lining Project is provided by Daly Hartin and colleagues (Daly Hartin et al. 2011); therefore, the following discussion provides more general information regarding the viscoelastic behavior of painting materials.

Time-Temperature Superposition

Over a wide range of test conditions, it is impractical to summarize tensile data from a viscoelastic material with stress-strain curves. It is also not feasible to measure the full relaxation behavior from glassy to rubbery—a process occurring over many decades—at one temperature, due to equipment limitations and time constraints. In figure 2.1, it is clear that a relationship exists between strain rate and temperature, since increasing the rate by an order of magnitude is equivalent to decreasing temperature by 10°C. This implies that time-temperature superposition (TTS) is a potential tool for efficiently summarizing data (Williams, Landel, and Ferry 1955). To illustrate this method, figure 2.5a shows a simplified summary of modulus values at three temperatures and four strain rates within a practical test window. This test window is bounded by equipment limitations and practical time available for data collection. Figure 2.5b shows the result of fixing data at a chosen reference temperature, T_{ref} = 20°C, and figure 2.5c shows horizontally shifting data at the other temperatures to line up as a single master curve. The result shows a shift from glassy to rubbery behavior over a broader scale than the experiments allowed in direct measurement. Tabulated results of the horizontal shift factor versus temperature allow one to create a master curve at any T_{ref} of interest within data limits. Defining T_{ref} at the glass transition temperature, T_g, would also allow comparison with theoretical functions, and possible extrapolation to temperatures beyond the test conditions. There are many reasons why the simple TTS method may not work for certain materials; however, it is a powerful tool when it does.

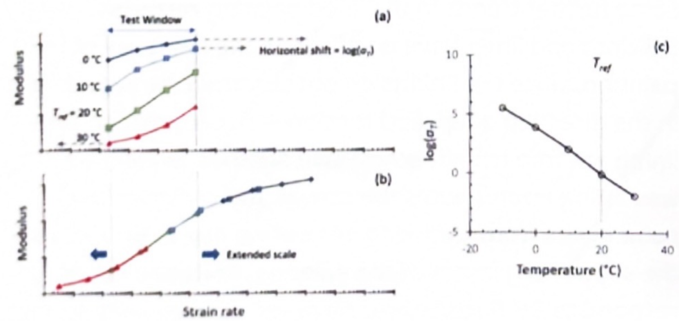

Figure 2.5 Illustration of time-temperature superposition applied to tensile test data. (a) Secant modulus measured at four strain rates and four temperatures. (b) Data at each temperature shifted along the time axis to form a master curve at T_{ref} = 20°C. (c) Experimental shift factor values recorded versus temperature. Image: © Government of Canada, Canadian Conservation Institute

It is helpful to consider practical situations where the viscoelastic properties are of importance. As a simple example, figure 2.6a shows a schematic of a broken and curled flake of paint that is deformed back into the plane of the painting. The radius of curvature (*r*) and film thickness (*h*) is labeled simply to highlight that it is possible to estimate the strain rate from a few parameters and define the time scale of the applied deformation. Rolling or unrolling a canvas painting is another similar and geometrically simple example. In figure 2.6b, the stiffness reduction caused by decreasing the rate of deformation is shown as the path from point A to point B along the master curve. In contrast, path A→C indicates the effect of keeping the same strain rate but using higher temperature to shift the master curve horizontally. The higher temperature accelerates the polymer relaxation and leads to a lower stiffness at a given strain rate. The horizontal shift may also be caused by a plasticizing effect, such as an increase in moisture content (Maksimov, Mochalov, and Urzhumtsev 1972). Path A→D shows a final example from the combined effect of decreasing the rate of deformation while also increasing temperature. Care should, of course, be taken when increasing temperature and moisture content, since extremes may cause unwanted effects beyond the simple relaxation process described here.

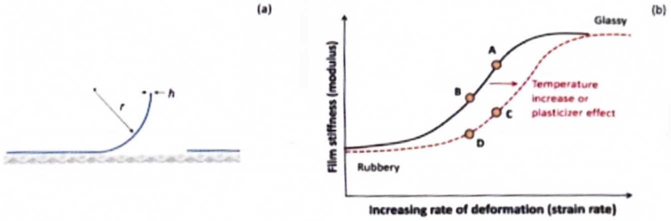
(a)
r
h
(b)
Glassy
A
B
C
D
Temperature increase or plasticizer effect
Film stiffness (modulus)
Rubbery
Increasing rate of deformation (strain rate)

Figure 2.6 Deforming a curled flake of paint back into the plane of the painting. (a) Illustration of the curled paint layer of thickness, *h*, and radius, *r*. (b) Effect of temperature and rate of deformation on film stiffness. A→B: slower rate of deformation, same temperature; A→C: elevated temperature, same rate of deformation; A→D: slower rate of deformation and elevated temperature. Image: © Government of Canada, Canadian Conservation Institute

The concepts discussed in this section are often studied using a technique called dynamic mechanical analysis (DMA) (Nielsen and Landel 1994). This can rapidly give modulus data as a function of temperature and frequency using a single sample and show transition regions. Experiments involving tensile tests are typically used when the large-strain response, or failure properties, are of interest.

Ultimate Properties

The purpose of using tensile test data in studies of artists paints is due to the interest in characterizing their large-strain response, particularly the failure criteria as a function of time and temperature. The related research work of Thor Smith in the 1960s is of interest since it shows the application of TTS to the ultimate properties of plastics and elastomers. Smith clearly summarizes an important finding in one of his many papers on this topic:

> The ultimate tensile properties (the stress at break σ_b, and the corresponding extension ratio λ_b) vary markedly with the temperature and with the stress-time or strain-time history prior to rupture. Considerable evidence indicates that data obtained at different temperatures can often be superposed to give master curves which show the variation of σ_b and λ_b over many decades of time at a fixed temperature. Further, the temperature shift factor is the same—or nearly the same—as that used to superpose viscoelastic data representing small-deformation behavior. In other words, the same molecular parameters which influence chain mobility, thus the time and temperature dependence of linear viscoelastic response, also have a controlling effect on the time and temperature dependence of the ultimate tensile properties. (Smith 1965, 275)

Recent studies on artists paints have highlighted the application of this approach for generating master curves of failure strains from tensile data. Figure 2.7a shows a generalized illustration of a failure envelope created using a similar approach to that shown for modulus data (see fig. 2.5). The path to point A results in failure before reaching the target strain at the defined strain rate. Reducing the strain rate avoids failure for the path to point B, which is outside of the failure envelope. Figure 2.7b shows the path to point C outside of the failure envelope due to a horizontal shift of the master curve from a temperature increase or possibly a plasticizing effect (e.g., increased moisture content). Combining higher temperature and reduced strain rate locates point D even farther from the failure line.

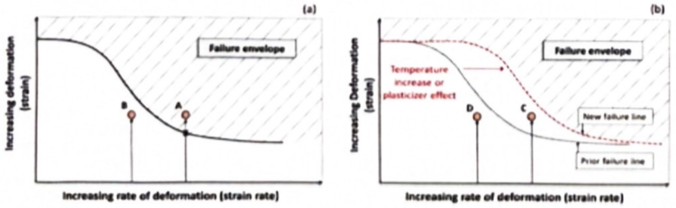
(a)
Failure envelope
Increasing deformation (strain)
B
A
Increasing rate of deformation (strain rate)
(b)
Failure envelope
Temperature increase or plasticizer effect
Increasing Deformation (strain)
D
C
New failure line
Prior failure line
Increasing rate of deformation (strain rate)

Figure 2.7 Deforming a curled flake of paint back into the plane of the painting. (a) Effect of reducing strain rate on failure criteria. (b) Effect of reducing strain rate and elevating temperature on failure criteria. Compare to figure 2.6. Image: © Government of Canada, Canadian Conservation Institute

This concept of a failure strain master curve is also shown in figure 2.8 using tensile data from two artists paint films at T_{ref} = 20°C (Hagan 2017). The acrylic paint film (fig. 2.8a) shows a considerably larger combination of strains and strain rates that avoid failure compared to the oil paint (fig. 2.8b). This illustrates why cracking of acrylic latex paints is much less common than in traditional oils over a wide range of conditions.

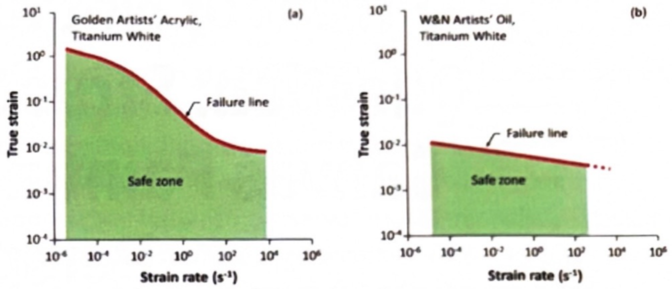

Figure 2.8 Failure strain master curves for two titanium white artists paint films at T_{ref} = 20°C. (a) Golden acrylic. (b) Winsor & Newton oil. Image: © Government of Canada, Canadian Conservation Institute

CONCLUSIONS

An overview of the viscoelastic properties of artists painting materials was provided to highlight important trends in their mechanical behavior. Example tensile test and stress relaxation data were presented for paint films and lined painting samples, respectively. These data showed a time and temperature dependence on measured stiffness and failure strains. For lined painting samples, stress-relaxation data indicated clear differences in the response of different treatment methods. The sailcloth lining showed value in maintaining consistent tension over time, potentially reducing the amount of strain on the painting for a given tension.

The concepts were further developed through a discussion of the time-temperature superposition principle and the creation of master curves of stiffness and failure strains. This technique can effectively summarize properties over a broad time scale and may be referenced at a temperature of interest. The master curves were used to illustrate how stiffness and failure strains are manipulated by changing the rate of deformation, temperature, or moisture content. In practice, it is not possible to know the shape of these curves for the wide variety of materials found in paintings; however, an understanding of the trends in material behavior is important when applying heuristics to treatment methods.

7

Sustainable Trajectories for Terminologies, Methods, and Materials in the Structural Treatment of Paintings on Fabric Supports

Matthew Cushman, Conservator of Paintings and Affiliated Assistant Professor, Winterthur Museum, Garden & Library, and the University of Delaware

Emphasizing international inclusivity and valuing regional and traditional practices, this paper offers recommendations for sustainable practice. The development of a multilingual, collaborative lexicon is favored over a standard terminology in English. Frameworks are proposed for practical research, dissemination of treatment information, and preparing for future challenges of material availability.

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INTRODUCTION

In his essay "Three Days That Changed Conservation," David Bomford reflected upon the circumstances surrounding the 1974 Conference on Comparative Lining Techniques and its status as an important inflection point in the history of paintings conservation: "It was the beginning of a new precision, a new refinement, and it heralded a new technical intelligence in targeting conservation treatments . . . Greenwich was when conservation came of age" (Bomford 2017, 1). What followed was a proliferation of approaches to treatment, coincident adoption of new materials, and a need for supportive fundamental and practical research.

The past forty-five years have seen technical refinements of traditional methods, changes in the ways that conservators communicate the nuances of structural treatment, engineering of new purpose-built equipment for lining and alternatives to lining, development of new approaches to lining, changes in material formulations, adoption of sophisticated research instrumentation, and increased international exchange of information. While the advances have been numerous, the challenges ahead are equally numerous and increasingly formidable. This paper attempts to anticipate some of these significant challenges and to provide a framework for sustainable collaborative efforts to address future difficulties.

THE CURRENT STATE OF TERMINOLOGY

One of the efforts of the Greenwich conference proceedings was the production of a handbook of terms used in the lining of paintings—an attempt to define about three hundred terms so that conservators from different countries and different lining traditions and philosophies could communicate effectively. This handbook was reproduced for subsequent conferences and seminars, and it is included as a glossary in the volume republished nearly twenty years ago (Villers 2003b). Despite the handbook's status as a key resource in the training of paintings conservators, and despite international efforts to standardize terminology in the realm of conservation of cultural heritage,[1] Cecil Krarup Andersen found in 2012 that the frequency of deviations from terminology established in the Greenwich handbook increased with the passage of time in English-language publications included in AATA, the Getty Conservation Institute's online database (Andersen 2012).

The reasons behind these deviations are many. Given the adoption of English as a lingua franca in conservation literature, Andersen and others have noted the persistence of English cognates in different lining traditions, resulting in a collection of terms having essentially the same meaning: lining, relining, doubling, and redoubling, for example. Additionally, the introduction of new materials and innovative approaches to treatment have given rise to adjustments to classical terminology and the creation of new terms and variants. Further confusion can result from techniques falling under umbrella terms while being fundamentally different procedures. For example, the thread-by-thread tear-mending techniques, first described by Winfried Heiber (Heiber 2003) and adapted by Petra Demuth and others, have influenced the development of various bridging and reweaving techniques for the stabilization and reestablishment of tension in torn supports. Of the two, reweaving may be more consistent with Heiber's approach, yet both approaches may be described as thread-by-thread tear mending or a modified Heiber technique.

One might suggest that our terminology has sprawled due to the lack of an explicit, unified imperative for international consistency. Inconsistent terminology may be cause for alarm; however, this "problem" is a natural consequence of parallel research and practical innovation that leverages the material traditions of varied regional practice. The expansion of our shared lexicon and authors' apparent agency to redefine accepted terminology suggests that the international community has engaged in rapid adoption of new techniques and materials to such a degree that flexibility has been valued over rigid language structures. To stifle experimental creativity by imposing specific linguistic constraints could strip some of the nuance from technical descriptions of practical applications—particularly if those communications originate outside of English-speaking traditions. If the trajectory of modern structural treatment is founded upon flexible decision-making trees—an intentional move away from prescriptive treatment—then it is imperative that paintings conservators aim to embrace and understand the breadth of traditions and techniques that exist internationally.

INTERNATIONAL COLLABORATION AS SUSTAINABLE PRACTICE

In the current global environment, with its mounting uncertainties due to climate change, political unrest, and public health crises, and given the limited resources allocated to the conservation of cultural heritage, conservators must seek out opportunities to create efficient practices. Shared knowledge, sustained longitudinal research, and the ability to anticipate future material challenges will have increased value in the decades ahead. Our best shot for rising to these demands is through international collaboration.

A Living, Multilingual Terminology

Of course, conservators must be able to communicate the technical aspects of their work with precision and clarity, and we must be willing to make nuanced adjustments to our terminology with the accumulation of scientific, philosophical, and practical information—shifting away from idealistic "reversibility" in favor of the practical "retreatability," and gaining a more granular understanding of increased transparency of oil paint films (van Loon 2008) due to deterioration processes and through structural intervention (Froment 2019), for example. Although the adoption of English as the operating language imposes some structure for a shared terminology, doing so also inhibits the participation and investment of experts globally, and we risk the erosion of nuance with each translation. If conservators embrace international collaboration as a benchmark of sustainable practice,[2] we will increase the probability of discovering new insights and relationships between differing international (and intergenerational) practices.

An updated terminology for the structural treatment of paintings on fabric supports—and indeed for topics within the specialty of paintings conservation and across disciplines—could be produced in the following manner:

1. Designate an international working group dedicated to the project.
2. Within each participating country and language, accumulate terminology and definitions as used natively.
3. Generate thesaurus entries to describe parallel terminology across languages.
4. Translate terminology and definitions for those terms that have no apparent equivalent from language to language.
5. Identify key literature to be translated across languages.
6. Perform iterative editing and expansion of the resulting living document.

This initiative would be a significant undertaking building upon and necessarily superseding efforts such as the Greenwich conference handbook of terms and the LMCR project spearheaded by the Associazione Giovanni Secco Suardo;[3] however, the benefits and potential efficiencies should be apparent to the reader, and the greater understanding and respect for traditions and innovations outside of the English language would help to build a more inclusive international community.

While parallels to medical fields might suggest that conservators should adopt a standardized lexicon, so much of the variation in our work is influenced by geography—the materials and techniques employed by the artist, the environmental conditions to which the painting has been subjected, and historical regional restoration practices—that a monolithic definition of best practice is neither reasonable nor sustainable. Rather, adopting a multilingual, multiregional approach to terminology would ensure that our common knowledge does not suffer an erosion of empirical nuance.

Ensuring a Sustained Pipeline of Applicable Research

Our terminology is only as good as our ability to fully understand the material demands of a treatment, and our ability to execute effective treatments depends on accurate heuristics and decision-making as well as appropriate use of purpose-built equipment. Each of these parameters is developed and delineated through fundamental and practical research. Our understanding of material properties and environmental response, the development of technologies and equipment in support of treatment refinements, and the evaluation of treatment procedures all require collaboration between conservators and scientists. Scientists ensure that research methodologies are sound, and that the interpretation of data holds scientific merit, and conservators ultimately decide how applicable the scientific research is to their daily practice, wherein conservators sort materials and techniques qualitatively (e.g., "weak" versus "strong" and "sympathetic" versus "invasive") for specific use cases.

A sustainable research pipeline for aspects of structural treatment might include the following:

- Distribution of research questions among multiple groups to accomplish as much as possible in an expedient manner
- Embedding of early and midcareer conservators and scientists into research groups to carry on projects when principal investigators retire or are otherwise unable to continue their work
- For materials research, aiming to describe the use limits of the material beyond ideal museum conditions
- Ensuring that research is not limited to high-tech or high-cost instrumentation, incorporating low-tech materials and qualitative, experiential observation whenever reasonable

In all cases, diversifying our pool of researchers, supporting the work of nonscientists in scientific studies, and ensuring long-term continuation of research projects will require more diverse streams of funding and coordination across projects.

Expanding Publication of "Ordinary" Treatments

Research only gets us so far toward understanding structural treatment. Ultimately, hands-on experimentation, practical treatment, and object-level study are supported by fundamental and practical research. A conservator's ability to recalibrate their heuristic understanding of treatment options relies upon an accumulation of data: experiential, anecdotal, and peer reviewed. Unfortunately for everyday practice, the conservation treatment literature is overwhelmingly geared toward the extraordinary: iconic paintings, material curiosities, and technical challenges. It can be difficult for a conservator to know when a project or observation is appropriate for or worthy of publication. Thoughts that this treatment is not interesting enough for publication or this painting is not important enough for publication are counterproductive in the long term, resulting in collective blind spots in the conservation literature.

A more sustainable and collaborative approach to this problem would be to encourage the publication of seemingly routine data about methods of manufacture and treatment procedures, either making room within established scholarly spaces or supporting new publication venues devoted to communications of "routine" treatments. This is an uncomfortable thought, however, for some practitioners and institutions, especially in the realm of conservation of modern and contemporary materials, wherein confidentiality is often key to the conservator-client (and conservator-client-dealer-foundation) relationship. We cannot expect colleagues to jeopardize their working relationships, but we should not feel satisfied by a discourse illustrated with redacted images and presentation slides with do-not-tweet warnings.

A reasonable compromise that would provide some degree of confidentiality while enabling the aggregation of treatment data would be to encourage periodic publication of treatments within an institution or private practice over the course of five to ten years. These summaries would overcome the misconception that individual treatments may not be worthy of publication, while tracking adoption and use of techniques and materials. Moreover, such publications would provide opportunities to discuss successes and shortcomings of treatments both ordinary and extraordinary. Lastly, this initiative would generate opportunities for conservators to think critically about their work and how their philosophies evolve over time. In sum, a critical mass of such publications would provide enough information to allow the field to better describe use boundaries between different structural treatment options in different exhibition and storage environments. Of course, this proposal hinges upon the support of existing editorial boards and/or the foundation of one or more new journals.

Increasing Practitioners' Command of Diverse Treatment Methodologies

An outgrowth of the production of a new international terminology and broader publication of practical treatment information (and indeed, of the Conserving Canvas initiative) should be the increase of conservators' capacity for understanding and commanding multiple approaches for structural treatment. The past few decades have seen a proliferation of new cleaning technologies aimed at greater specificity, efficacy (Ormsby et al. 2010), control (Tauber et al. 2018), and increased safety to the practitioner.[4] Yet the same demand for specificity in structural treatment is seemingly lacking; a paintings conservator might be expected to utilize only a few structural treatment procedures each for humidification, consolidation, tear mending, and lining. One goal of modern structural treatment should be to work toward the understanding of and proficiency in multiple techniques to service different needs and to achieve differing effects.

The ways in which we describe treatment parameters can be expanded by considering varied approaches. For instance, a more nuanced understanding of treatment possibilities allows us to better define one's intent with a treatment: whether or not adhesive methods are required, and if they are, where within the structure of the painting one aims to localize the adhesive bond, and what is intended for the method of retreatability. From there, the choice of materials and the ability to control the conditions imposed upon the painting during treatment determines (in part) the success at realizing the intent of the treatment.

An individual conservator, a training program, and a museum might have their own proficiencies when it comes to structural treatment; by relying upon one another, we are able to fill in knowledge gaps and develop formal and informal advisory groups to guide individual treatments and long-term practical advancement. An ancillary benefit of gaining proficiencies across several different types of structural treatment is an increased ability to adapt when working in nonideal conditions or when material formulations change.

Material Sustainability and Probable Impacts on Structural Treatment

In recent years, sustainability has transformed from a buzzword to an urgent concern. Increased focus has been placed upon material sourcing, with specific attention paid to materials refined from petroleum and other nonrenewable resources. Other key factors in material sustainability are environmental impact (how a material influences the stability of various biomes) and human health and safety (how chronic and acute exposures affect organ function and how materials metabolize and bioaccumulate within the body). One consequence of pursuing sustainable materials and practices is the greening of our chemistry, either by choice or through governmental regulations.

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Of the various regulatory frameworks worldwide, the European Union's Regulation, Evaluation, Authorization and Restriction of Chemicals (REACH) is a good predictor of materials to which conservators might lose access in the near future.[5] Under REACH is a list of substances of very high concern (SVHC): a register of chemicals that are deemed problematic and have been proposed for restricted use or other regulations. Suppliers and manufacturers can receive authorizations to formulate substances containing restricted materials; however, if a manufacturer were to find a substitute chemical that performs similarly while being unrestricted, there is a strong likelihood that the formulation of the substance will change. For the purposes of structural treatment, conservators need to be aware of the current formulations of our common materials and the chemical similarities between components of conservation materials and those on the SVHC list.

Although the number of changes to paintings conservation practice resulting from governmental regulations should be low, there are examples of anticipated changes that are of significant concern. Phthalates feature in general on the SVHC list,[6] mostly because of the risk of oral exposure due to the presence of phthalate plasticizers in children's toys and in plastic bottles. The most common occurrence of phthalates in paintings conservation is in the formulation of Beva 371 and Beva 371b, both of which include Cellolyn 21, a phthalate ester of rosin acids.[7] Replacing Cellolyn 21 in the formulation of Beva products will likely change the tacking, setting, and melting temperatures of the adhesive.[8] Phenol ethoxylates, a class of nonionic surfactants, are under increasing scrutiny.[9] Nonylphenol ethoxylates, for example, are restricted materials under REACH, but they have been used in the past in formulations of acrylic dispersions. It is likely that the surfactant components of acrylic dispersions will undergo a series of substitutions, possibly resulting in different working properties and changes to the pH of acrylic dispersion formulations. Lastly, some of our common solvents have been deemed problematic, including many aromatic solvents. Any restrictions placed upon these solvents could have implications for reversibility of certain treatments and for the feasibility of some adhesive formulations.

In addition to material substitutions due to governmental regulations, conservation materials extracted from threatened or endangered species may not be available in the future. Examples of these species include many types of sturgeon, from which protein glues can be extracted, and some algae species responsible for the production of agar-agar and agarose. Conservators need to be aware of the possibility of formulation changes. Not only do we have a moral obligation to comply with regulations, but we also have an ethical obligation to anticipate material changes and the impact such changes may have on retreatability of current treatments. Luckily, being prepared for changes in the name of sustainability can be accomplished by attempting to address all of the challenges highlighted above.

CONCLUSION

Our ever-evolving understanding of the structural treatment of paintings on fabric supports is built upon nuance and experience expressed first in native tongues and shared across cultures thereafter. If conservators and scientists can work together to communicate effectively and efficiently, to explore the limits of our current techniques, to respect the expertise inherent in regional traditions, and to encourage fundamental and practical research within our international conservation framework, we will have followed sustainable and adaptable trajectories for progress. These collaborative efforts will be most effective if we avoid impulses toward secrecy and proprietarianism, embrace communications detailing treatments and studies, both routine and extraordinary—whether they be successes or failures—and plan ahead for conditions where problematic or scarce materials need to be replaced. Thus, multilingual and multiregional inclusiveness will provide the field with a plurality of best practices to adopt, adapt, and evolve into the future.

NOTES

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1. For example, European Committee for Standardization CEN/TC 346/WG 1, General methodologies and terminology: https://standards.cen.eu.
2. International partnerships are among the United Nations' seventeen Sustainable Development Goals: https://www.un.org/sustainabledevelopment/sustainable-development-goals/.
3. The Multilingual Technical Scientific Glossary in Conservation and Restoration was a multiphase project (2001–7) focused on the production of a common thesaurus in English, German, French, Italian, and Spanish. See http://www.associazionegiovanniseccosuardo.it/?q=en/node/163.
4. For several examples, see Angelova et al. 2017.
5. https://echa.europa.eu/regulations/reach/understanding-reach.
6. At the time of this writing, eighteen different phthalate esters are included on the SVHC list.
7. See http://cameo.mfa.org/wiki/Cellolyn.
8. At the Conserving Canvas symposium, Michael Swicklik, senior conservator of paintings at the National Gallery of Art, in Washington, DC, related an anecdote from his time working with Gustav Berger wherein Berger explained how Beva 371 did not function as intended without the addition of Cellolyn 21.
9. At the time of this writing, twenty-seven different phenol ethoxylates are included on the SVHC list.

6

Structural Conservation of Canvases in Russia from the 1960s to the Present: Evolution of Methods and Approaches

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The Russian school of oil paintings conservation has come a long way since the 1960s—from applying only traditional structural treatment techniques with water-based adhesives to accepting modern approaches and synthetic polymer materials. This article is devoted to the milestones achieved during this process. Transformation of traditional lining methods is discussed, including changes in procedure and formulations. The paper also covers the development of less-invasive conservation techniques (such as tear mending, sizing, and hydrophobization) and putting them into practice.

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INTRODUCTION

The tradition of Russian conservation officially started in 1743, when the German artist Lucas Conrad Pfandzelt came to Saint Petersburg to care for the royal painting gallery. During the first decades of its existence, conservators established main principles that were retained for about two centuries. One of these was sticking to a complex structural treatment that would always include such serious interventions as transferring paintings from their original supports and, of course, lining (Alyoshin 1989, 55).

For a very long time after the October Socialist Revolution of 1917, conservation in Russia developed in isolation from the rest of the world. With the beginning of the thaw period in Soviet culture (from the mid-1950s to the mid-1960s), the sphere of heritage preservation experienced significant evolution, and the restoration community started to wander away from techniques developed in the nineteenth century. In 1957, with the founding of the All-Union Central Research Laboratory for Conservation and Restoration of Museum Valuables,[1] conservation science in Russia gained momentum; however, it was not until the 1960s that conservators of easel paintings were able to access professional literature and scientific events from abroad to learn about methods used in current practice by their foreign colleagues.

These developments coincided with advances in the chemical industry—all of which set the stage for big changes in the conservation field in Russia. Analyzing professional scientific journals published in GOSNIIR in the 1960s,[2] we can see a deep interest in chemical research into objects. The use of new synthetic materials for consolidation, the study of biocide agents, and the use of new conservation equipment such as vacuum hot tables were discussed. During this period, worldwide experience was collected and evaluated. Some journal issues were devoted solely to reviewing specialized essays for museum conservation professionals.[3]

From the 1960s to the 1980s, Soviet conservators reviewed, created, and adapted structural conservation techniques, some of which were considered to be a quantum leap in our country. At that time, the most successful branch was on the track of choosing noninvasive methods (as they were understood then). Despite some new approaches introduced to the professional community during the Greenwich Conference on Comparative Lining Techniques (Villers 2003b), Soviet conservators would not turn away from natural materials and traditional methods. But the drive to make treatments less invasive and more reversible triggered a significant number of research projects. Such operations as tear mending, consolidation of the flaking paint layer, and improvement of deformations were reconceived in order to avoid dipping canvases in collagen adhesives and to delay lining for as long as possible.

TRANSFORMATIONS OF TRADITIONAL LINING TECHNIQUE

From the beginning of the 1960s until the mid-1980s, attention was particularly given to the traditional lining technique. A lot of experiments were undertaken to work out best recipes (Lelekova 1966, 107–8) or to pick plasticizers. Historically, natural honey was used for this purpose, but its effects and properties in lining compounds were always questioned. In 1960, research on different lining adhesives was published in which specialists from State Central Arts and Conservation Studios[4] discussed shrinkage of sturgeon-glue films, both pure and with different added plasticizers. As a result of their experiments, the authors proposed using polyvinyl alcohol with glycerin, as these materials guarantee a more predictable effect, whereas the plasticizing properties of honey were considered insignificant and very much dependent on the amount of sucrose in its composition (Trostyanskaya, Tomashevich, and Sorokina 1960, 181–82).

However, the results of this research were not widely applied in practice. New instructions and publications would still recommend that conservators use compounds for lining made up of different proportions of sturgeon glue and honey. For example, Margarita Alekseyeva and Zinaida Tcherkasova in an article on aqueous lining solutions mention all the known drawbacks of sturgeon glue–honey compounds but still include the recipes in their guidelines (Alekseyeva and Tcherkasova 1968, 19–21).

The authors offer two practical methods of performing the process of lining canvases. The first is based on a recipe with a 1:1 ratio of honey to dry sturgeon glue, by weight. It suggests that the lining canvas be glued three times: the first two with a 4%–8% solution and the third with an 8%–10% solution. All three layers of glue should be dried in sequence. The original canvas is covered with a 3%–6% water solution of sturgeon glue with honey. After it dries, a second layer of 8%–10% solution is applied. As this second layer becomes tacky, the two canvases are joined, evenly pressed together, and ironed using warm and cold irons alternately until the condensed moisture stops being released.

The second method is based on a recipe with 2:1 ratio of dry sturgeon glue to honey, again by weight. The lining canvas is prepared with two layers of warm 6%–8% solution of sturgeon glue and honey. The original canvas of the painting is infused with the same compound from one to five times, with each layer being allowed to dry between coats. Before the lining procedure, both canvases would be infused with a 12%–17% solution prepared in a proportion of 2–3:1 of dry sturgeon glue and honey, respectively. As the layers on both canvases become tacky, they are joined evenly and left to dry in a vertical position for three to six hours. After that, the canvases are ironed using warm and cold irons alternately until the condensed moisture stops being released (Alekseyeva and Tcherkasova 1968, 22).

Several years later these methods and their variations were included by Ivan Gorin and Zinaida Tcherkasova in a chapter of a text for art colleges teaching conservation; it remained the most popular guide to practical restoration for at least twenty years (Gorin and Tcherkasova 1977, 126). Interestingly, it also has chapters on structural treatments with wax-resin adhesives that were already falling out of practice by that time.

In 1974, Larissa Yashkina made a presentation at the Greenwich conference, basing her speech on a variation of the first method described above, though she offered slightly different formulations of the lining compounds and gave more technical details about the procedure (Yashkina 2003). It was a more common method at that time and considered to be more reliable.

Further investigations on sturgeon-glue lining compounds were conducted in the 1970s and 1980s. In 1975, Roza Yabrova presented a paper discussing some new materials for plasticizing sturgeon glue (Yabrova 1975). Her comparative research showed that such additives as polyethylene glycol (trade name PEG 600), carbamide, and sorbitol could replace natural honey without all its problems and drawbacks. But traditions seem to be extremely strong among the Russian conservators, as none of these materials were adopted in standard practice, so later research continued to focus on sturgeon-honey solutions—as well as concentrating on solving the problem of collagen glues being prone to biodeterioration (Nazarova 1984; Nazarova and Potapov 1984; Rebrikova 2013).

Nowadays traditional lining technique is still one of the most common methods of consolidation of original canvas supports of the paintings. But during the past ten years, there has been a significant change in the whole procedure. First of all, sturgeon has become an endangered species in Russia—since 2013 it has been protected by a federal law that limits sturgeon fishing and processing. The State Research Institute for Restoration has studied rabbit-skin glue as an alternative to sturgeon glue and came to the conclusion that if used in less-concentrated solutions, rabbit-skin glue can be successfully applied to consolidate paint and ground layers and also used for lining.[5]

Moreover, there is now a trend toward reducing the amount of additives in the lining compounds. As the storage and exhibit conditions in Russian museums have generally become more stable—with balanced temperature and humidity—there is no need to add biocides and plasticizers during each treatment. Case studies demonstrate good results for paintings that were treated with collagen glue solutions without honey (Alyoshkina 2015; Voronina 2019; Yurovetskaya 2016).

TREATMENTS TO POSTPONE LINING

In the 1970s and 1980s, leading studios and institutions evolved new methods of preserving linen canvases that are still widely used in conservation practice in Russia. One of the most vivid examples is a tear-mending technique developed at GOSNIIR in the 1970s that is still widely used by conservators throughout the country (Surovov and Yashkina 1979). It suggests that tears and cuts of the textile painting supports are treated with 5% solution of polyvinyl butyral (PVB) in ethanol or isopropanol. Saturated threads are interwoven and after drying are fixed using a hot spatula. This adhesive has been widely used in conservation practice in Russia since the 1950s (Rumyantsev 1953), especially for treating murals, ceramics, and fabric painting supports. Its glass transition temperature (Tg) is approximately 60°C–70°C. "PVB films are resistant to light and heat-sealable at temperatures above 120°C ... PVB films are noted for their biostable and abrasion resistance properties as well as for good colorfastness against UV light, low static generation, and low water absorbtion" (Sannikova 2018, 106). In 2008, the tear-mending technique was slightly extended by adjusting the method for strip-lining two-sided paintings to avoid overlaps of new margins over the paint layer (Yashkina and Churakova 2013). The working procedure has also slightly changed. Following a general trend holding that less is more, conservators tend to use less adhesive for the process: instead of saturating canvas around the tears, they just apply it to the direct spots.

A method of stabilizing canvases by starch sizing was introduced by conservators of the State Tretyakov Gallery and came into common practice as a procedure for conserving canvas (Yushkevich 1995). The technique was first developed in the 1970s but was not published until the mid-1990s, being constantly improved in the interim by its author, Galina Yushkevich (Yushkevich 1995).

Before performing the operation, the picture must be stretched on paper margins; the painting layer should be fully covered by the facing. These precautions guarantee that the canvas of the painting is kept from shrinking during treatment, which involves heat and moisture. Afterward, the painting is put facedown on a flannel or woven felt to protect the impasto. Sizing is performed by applying a 10% starch paste on the reverse of the picture and spreading it evenly. After the paste dries a little, it is delicately removed with a palette knife. The small amount of remaining starch is pressed with a warm iron. This causes the residue of the paste to be absorbed into the structure of the picture, which helps reduce canvas deformations and makes the support less responsive to changes in temperature and humidity.

This method is effective for treatment of canvas undulations, so it was adopted by many conservators and is still widely used in many studios. However, during the past few years this method has been reevaluated. Saturating canvas with starch ultimately makes the linen fibers more brittle and prone to microbiological damage. Nowadays cellulose ethers are mostly substituted for the starch; this also functions to better adsorb dust and glue residues from the canvas (Churakova, Karasyova, and Yurovetskaya 2018, 56), but such total saturation of fabric support is still debatable.

In the late 1980s, another interesting technique used to stabilize canvas supports was introduced by GOSNIIR: hydrophobization of textile supports with solutions of organosilicons in isopropanol or refined gasoline (Malachevskaya and Yashkina 1986). Two coats of a 5% solution of polymethylhydrosiloxane are applied sixty minutes apart by brushing or spraying onto the reverse side of the picture. This coats the textile fibers and reduces the canvas's response to changes in temperature and humidity. The process of polymerization is usually finished after eight to ten days of exposure, when the solvent evaporates. The properties of organosilicons (such as polymethylhydrosiloxane) still allow for later protein glue treatments, including sturgeon-glue linings (Fedoseeva 1999, 68–69).

Evaluating methods of hydrophobization of canvases with solutions of organosilicons seems to be a more complicated task for now. All tests performed with the samples showed very good results. According to publications on the project, treated canvases quickly repel surface moisture, do not get wet, are not prone to shrinkage and deformation, and withstand sharp increases in humidity (Nazarova, Malachevskaya, and Yashkina 1990). Furthermore, the air and vapor permeability of canvases did not change (Malachevskaya and Yashkina 2013). However, when this treatment was applied to the paintings, it turned out that on some artworks the consolidation operations with water-based solutions were not as effective as they were on the untreated paintings with organosilicon objects. Moreover, the process of degradation of polymethylhydrosiloxane is still to be investigated.

ACCEPTING GLOBAL TRENDS AND MATERIALS

We did not have an industry dedicated to conservation products in the former Soviet Union, nor do we currently have one in Russia. None of the polymers that have been studied, tested, and applied were produced specifically for conservation purposes; all of them were created for the production sector and then adapted to conservation needs. In the 1990s, not only the political but also the economic life of our country underwent serious changes after the collapse of the Soviet Union. Many manufacturers either closed or changed production technology, afterward offering new materials to the market. At the same time, importation of European and American conservation materials started to grow, so people working in the conservation and restoration sphere suddenly had a broad selection of totally new polymers to get acquainted with. Consequently, the beginning of the new period in Russian history started with much experimentation, comparative work, and research in the conservation field. Specialists returned to the international conservation community, attending conferences and scientific seminars and learning more about the work of their foreign colleagues. At this time numerous tests were also carried out, including those on materials for structural conservation of canvases.

GOSNIIR conducted comparative research on three acrylic dispersions: Lascaux 498 HV (Lascaux Colours & Restauro) was compared to two adhesives originally produced in Russia for coated paper and textile manufacturing. The first has the trade name ABV-1B and is a copolymer of butyl acrylate, methacrylic acid, and vinyl acetate. The second has the trade name AK-243 and is a copolymer of ethyl acrylate, methacrylic acid, vinyl acetate, and acrylonitrile. Both have a working concentration of up to 50% (Fedoseeva et al. 2016, 98–99). All three dispersions meet the general requirements for a strip-lining adhesive: they do not penetrate deeply into the threads of the canvas, they do not cause shrinkage of the canvas, they have a high adhesive capacity, and they form a film with elasticity that persists over time.

Results of the comparative analysis showed that the AK-243 and ABV-1B dispersions are superior to the Lascaux adhesive on a number of indicators; in particular, they penetrate less into the threads of the canvas and do not cause shrinkage (Fedoseeva, Malachevskaya, and Yashkina 1997). Nevertheless, today the most popular adhesives for strip-lining are Beva products (Beva 371 Film or Beva D-8 Dispersion) and Lascaux 498 HV (Romanova 2019). This is despite the fact that both AK-243 and ABV-1B are still produced in Russia: manufacturers sell them only in industrial-scale volumes and retailers are not interested in organizing packaging the products in smaller sizes, thus conservators have problems obtaining them.

Following international trends, in the 1990s the Russian conservation community started to familiarize itself with synthetic materials for lining and to compare them with traditional techniques (Fedoseeva 1998). There was also the intent to develop or adapt Russian synthetic polymers for the lining process.[6] In the end, an understanding that the most common sturgeon-glue lining has obvious drawbacks and is not suitable for all artworks led to adopting a method for treating oil paintings that has been well known for lining textiles since the 1970s, when it was introduced at the Pranas Gudynas Centre for Restoration in Lithuania.

The method employs an acrylic adhesive with the trade name A-45-K, which is a copolymer of vinyl acetate, butyl acrylate, and acrylic acid in ethyl acetate (Emelyanov 2005). In a form of either a dispersion or acetone solution, it can be brushed or sprayed on a lining cloth and later activated by temperature (Semechkina 1993, 125). Its properties are in many ways similar to Plextol and Lascaux adhesives, but choosing a local manufacturer was preferred in the 1990s.

not only to support the country's economy but also because this particular material was well known and tested. A-45-K has not become very popular for standard lining procedures for canvases, but it showed good results in a few specific case studies.

One example is the lining support of the eighteenth-century painting *Conclusions of Field Marshall General Count B. H. Minikh on the Seizure of Ochakov* (fig. 6.1) (Iurovetskaia et al. 2019). Silk was used as a support (fig. 6.2), and the image layer combined oil, gold paint, and ink. Adhesive A-45-K dissolved in acetone was sprayed on the surface of the lining cloth (fig. 6.3) and after matching with the original support was activated locally by heat (fig. 6.4). Effective application of A-45-K for this art piece still has not led to widespread adoption of this technique among professional conservators because, since 2006, when this method was first introduced for lining the Mikhail Vrubel painting *Gwydon* on a sackcloth support, it has become increasingly complicated to acquire the material from the manufacturers.

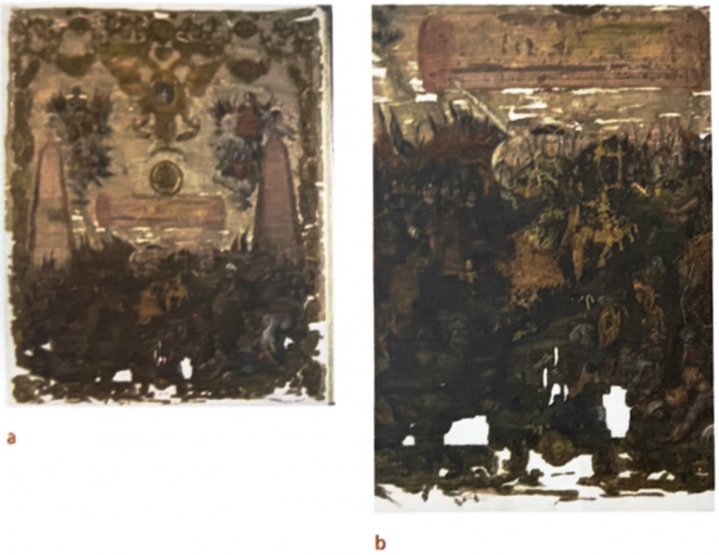

Figure 6.1 Unknown artist, *Conclusions of Field Marshall General Count B. H. Minikh to the Seizure of Ochakov*, 1737. Mixed techniques on silk, 172 x 143 cm (67 3/4 x 56 1/3 in.). (a) After removing old facings. (b) Detail. Image: © State Historical Museum, Moscow

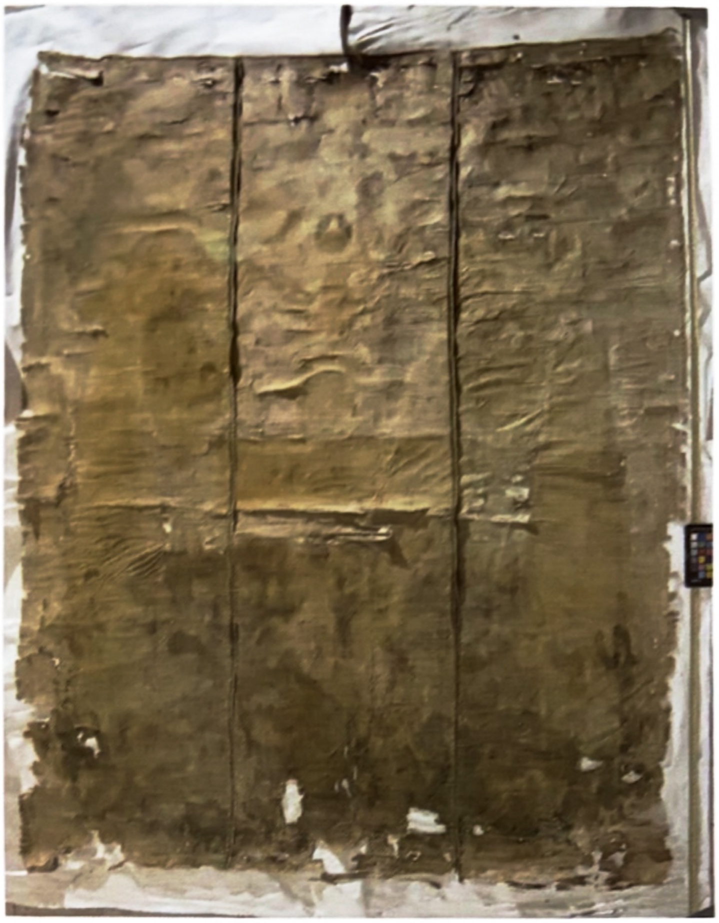

Figure 6.2 Back side of the painting in fig. 6.1 after removing old facings; silk support in raking light. Image: © State Historical Museum, Moscow

Figure 6.3 Fragment of lining textile sprayed with adhesive A-45-K. Image: The State Research Institute for Restoration, Moscow

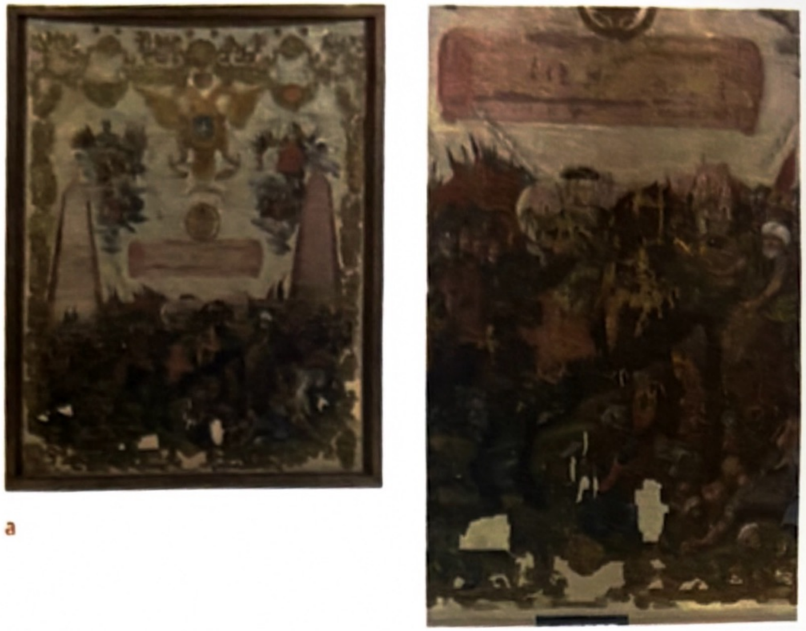

Figure 6.4 *Conclusions of Field Marshall Minikh*. (a) After structural treatment. (b) Detail. Image: © State Historical Museum, Moscow

Nowadays restoration professionals in Russia often face difficulty accessing materials adapted for conservation purposes in our country and thus turn to reliable professional materials by internationally known suppliers. In this way, the conservation field in Russia is experiencing globalization, with all its challenges and opportunities, and mostly sticking to materials and techniques that are used worldwide. This certainly makes our work more comfortable, but it also eliminates distinctions between different conservation schools with their unique methods and approaches.

NOTES

1. Later reorganized into the All-Union Research Institute for Restoration, now called the State Research Institute for Restoration (GOSNIIR).
2. The online library of GOSNIIR includes periodicals from 1960 to the present: http://www.gosniir.ru/library/artistic-heritage.aspx.
3. *Reports of All-Union Central Research Laboratory for Conservation and Restoration of Museum Valuables*, issues 12, 15, and 22–23 (1964–70). http://www.gosniir.ru/library/artistic-heritage.aspx.
4. Later reorganized into the All-Russian Scientific Restoration Center, now called the Grabar Conservation Center.
5. "Studying the Properties of Rabbit Skin Glue," archival fonds of GOSNIIR, no. 1, inventory 37, 2013, p. 51.
6. "Developing Method of Lining Easel Oil Paintings Using Russian Synthetic Materials," archival fonds of GOSNIIR, no. 1, inventory 13, folder 105, 1992.

8

The Relining of Van Dyck's *Equestrian Portrait of Charles I*

Paul Ackroyd, Conservator, National Gallery, London

The previous conservation treatments of Anthony van Dyck's **Equestrian Portrait of Charles I** *present a history of lining. Having been lined with a glue-paste adhesive twice in the late nineteenth century, the painting was relined with a wax-resin adhesive in 1952, and in the recent treatment was relined with Lascaux 375, an equivalent heat-seal adhesive to Beva 371. This article describes the recent treatment, starting with the removal of the wax-resin lining, and includes the repairs to the original canvas and the relining, which was carried out in two separate stages on a heated low-pressure table while the painting was held in a vacuum envelope.*

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INTRODUCTION

The *Equestrian Portrait of Charles I* by Anthony van Dyck (NG 1172), painted around 1637–38 and monumental in scale (368 × 292.5 cm), imposingly depicts the king as the divinely chosen ruler of Great Britain, celebrating the union between England and Scotland following the accession of Charles's father, James I, to the throne in 1603 (fig. 8.1). Van Dyck's choice of an equestrian portrait not only demonstrates the king's horsemanship but is also deliberately reminiscent of equestrian statues in ancient Rome that were intended as assertions of temporal power. It was painted toward the end of a period of relative prosperity in England and set in a tranquil English landscape, shortly before the country was plunged into a bloody civil war in which Charles lost the throne—and his head, when he was executed on January 30, 1649. The depiction of this poignant moment in English history has ensured its popularity with visitors to the National Gallery and its importance within the collection. Only rarely has it been taken off display, and it normally hangs in room 31, where it creates an imposing impression and forms a vista to draw the public into the gallery as they enter through the Central Hall.

Van Dyck painted the portrait on a twill weave canvas with a black ticking pattern, which has a central horizontal join (fig. 8.2); it bears Charles I's original cipher at the center of the reverse. This type of canvas, commonly used for domestic upholstery, was probably chosen for its strength and toughness and because it could be obtained in large widths, making it an attractive choice of material for large paintings. The canvas was prepared with a red-brown ground followed by a thick, oil-based gray priming.

The decision to fully retreat the picture in 2018 was based on the fact that the lining canvas was detaching from the original and the previously applied varnish and retouchings had discolored significantly. All lining activity at the National Gallery since the late 1970s has entailed the relining of paintings—that is, the replacement of an old and degraded lining with a new one. On the occasions when previously unlined pictures have required structural attention, less-invasive forms of treatment than lining have

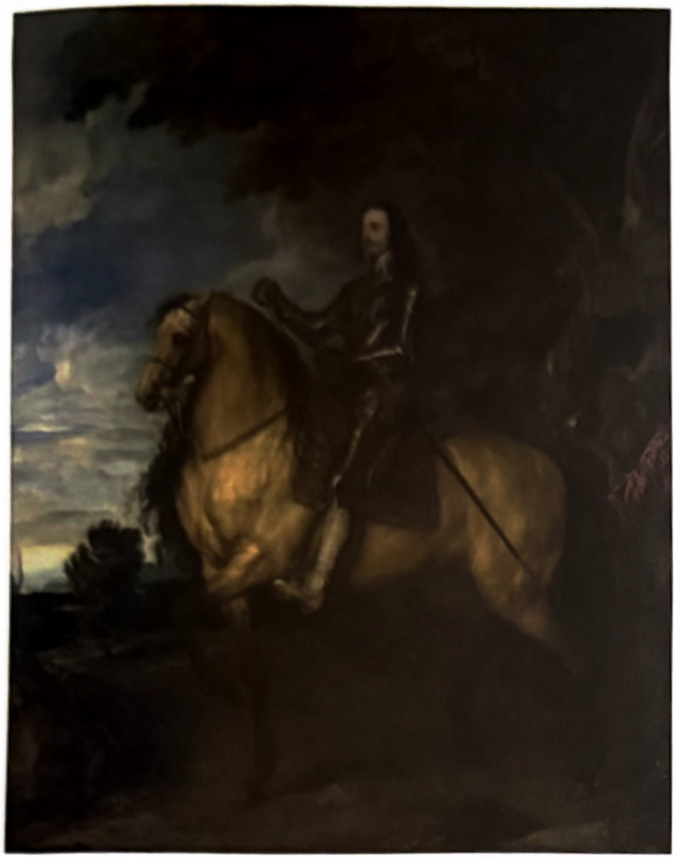

Figure 8.1 Anthony van Dyck (Flemish, 1599–1641), *Equestrian Portrait of Charles I*, 1637–38. Oil on canvas, 368 × 292.5 cm (144 7/8 × 155 1/8 in.). Before treatment. Image: National Gallery, London

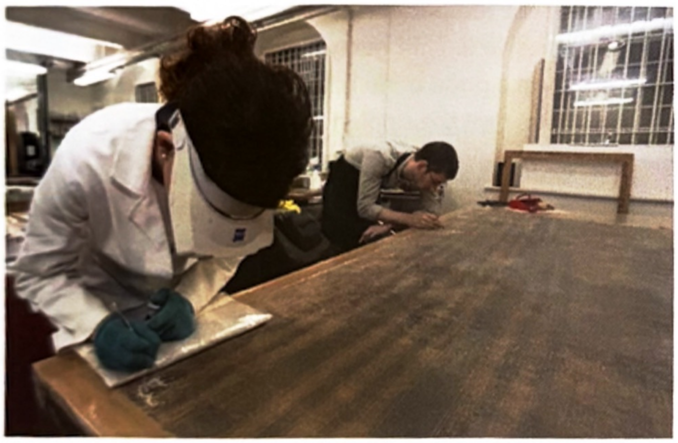

Figure 8.2 Van Dyck's *Equestrian Portrait of Charles I*. Detail of the canvas reverse showing the black ticking pattern. The wax-resin adhesive is being removed in this photograph. Image: National Gallery, London

been selected. In the case of the Van Dyck, the recent relining was a nonimpregnating, nap-bond treatment carried out with an equivalent of Beva 371, Lascaux Heat-Seal Adhesive 375, using a vacuum-envelope technique.

EARLY HISTORY AND OWNERSHIP

The painting's checkered early history has affected its condition. In 1650, shortly after Charles I's execution, Cromwell sold the painting to Sir Balthazar Gerbier, who resold it to Gisbert van Ceulen in Antwerp, from where it was sold yet again to Duke Maximilian II Emanuel, elector of Bavaria and governor of the Spanish Netherlands (Martin 1972, 44). In 1698, the painting was looted from Munich by Emperor Joseph I, who gifted the picture to the first Duke of Marlborough in 1706. From then, it remained in the United Kingdom at Blenheim Palace until the National Gallery acquired it in 1885 for the sum of £17,500. Throughout all these changes in ownership, the painting would have been rolled up and transported by horse and cart or by ship. The raised, horizontal craquelure in the picture is indicative of the painting having been rolled, as are the large number of splits and losses at the sides (fig. 8.3). A series of vertical losses at the right edge also suggest that the rolled canvas was tied too tightly, crushing the paint in these areas.

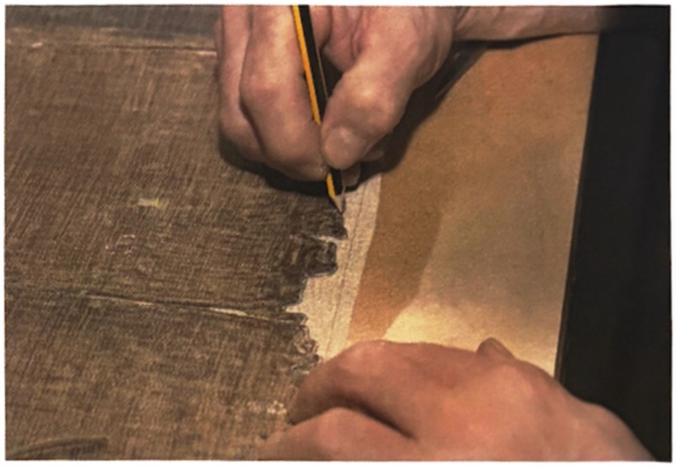

Figure 8.3 Van Dyck's *Equestrian Portrait of Charles I*. Detail of the canvas reverse showing the splits at the sides during their repair with inserts of new primed canvas. Image: National Gallery, London

Since the painting entered the National Gallery's collection it has rarely traveled. During World War I, the picture was evacuated to Overstone Park, outside of Northampton. During World War II, it went first to Penrhyn Castle, and then in 1941 to the Manod slate mine in Wales. On both of these latter occasions, it was transported upright on its stretcher in a large wooden case strapped to the back of a lorry. On its journey to Manod, the truck had to pass through a tunnel that was not tall enough to accommodate the height of the case. This had been anticipated, and the road had been dug up beforehand to make extra height, but even so there was insufficient headroom for the truck to pass through, and the truck's tires had to be deflated (Clark 1977, 6; Davies and Rawlins 1946, 13). On its return trip to the National Gallery in June 1945, the painting traveled mostly by train. More recently, in January 2018, the painting was lent to the Royal Academy's exhibition *Charles I: King and Collector*, and it again remained on its stretcher for the short journey across London.

EARLY RELINING TREATMENTS

Before the recent treatment, which began with a cleaning in June 2018, the painting had already been lined at least four times; as a result, it presents a potted history of lining at the National Gallery. It was acquired already lined, almost certainly with a glue-paste adhesive, and relined immediately after acquisition with glue-paste by William Morrill, a private liner who regularly undertook work for the gallery. Morrill was the second generation of a dynasty of liners renowned for their tough, durable linings—which, by today's standards, often produced overly flat picture surfaces. In the case of the *Equestrian Portrait*, this was achieved at the expense of squashing the impasto in the picture, leaving moated depressions around these areas.

It is worth emphasizing the durability of the Morrill family's linings, a number of which still remain on National Gallery paintings, and they have stayed in a stable condition despite now being around 170 years old. In 1889, however, four years after his initial lining, Morrill was asked to reline the painting again, because it was considered that the central join protruded too much. This time he did another paste relining but using two lining canvases. However, this lining created further damage. Morrill cut away all the excess canvas at the back of the join and completely removed the stitching in the central section as well but left the stitching intact at the ends of the join. During the relining, the two original pieces of canvas shrank apart, leaving a 4–5 millimeter gap across the center of the join, and at the points where the stitching remained, the painting bulged away from the lining canvas, forming large air pockets. The bulge at the left was ironed flat, leaving a slight depression, but ironing the one at the right created a raised crease in the original canvas and a 50-centimeter-long vertical line of paint loss. A similar crease was made in the center of the bottom edge. Additionally, during the lining removals that Morrill undertook, fragments of old glue became trapped underneath the picture, causing holes and indentations in the picture surface, mostly around the edges.

By 1952, Morrill's lining canvases had embrittled, tearing at the turnover edges, and the surface of the painting had become undulated. By this time the gallery no longer used private restorers, having established a conservation department in the late 1940s. Arthur Lucas, who later became the gallery's chief restorer, decided to remove Morrill's double lining using a mixture of water and ethanol to soften the glue layers, and to then reline the painting with a single piece of linen adhered with a wax-resin mixture (58% plain beeswax, 40% dammar resin, 2% stand oil) using heated hand irons. There was a vogue for wax-lining at the gallery from shortly after the war until the late 1970s, when it was supplanted by Beva 371. Lucas's decision to reline the picture may have been considered legitimate at the time, but nowadays it might be considered more appropriate to flatten the undulations and repair the edges of the lining by adding a strip-lining.

Lucas's lining also had its problems. The water and ethanol used to remove Morrill's lining made the original canvas buckle and undulate, and these problems were not addressed with any flattening treatments before relining. The relining was initially carried out with the painting facedown, and the lining canvas, stretched onto a loom and prepared with the wax resin, was placed on top of it—a standard procedure at the time. The lining canvas was ironed from the reverse, lightly tacking the painting to the lining, which was then turned faceup so that the ironing could continue over the facing tissue covering the front of the picture. The temperature of the irons was reduced, and the wax adhesive did not get hot enough to form an even layer nor form a good bond between the two canvases. The result was that the rippled undulations caused during the delining remained and, due to the considerably uneven distribution of wax, more pronounced lumps and bumps were created in the picture surface (fig. 8.4). By 2018, the painting was detaching from the lining, particularly at the edges.

THE RECENT TREATMENT

Removal of the Old Lining

After cleaning, a template was made of the damages and distortions at the front by marking these areas onto thick sheets of Melinex (polyester film), so that they could be accurately located on the back of the picture during the later stages of the treatment.

The central join was then faced with Japanese tissue adhered with a wheat-starch and sturgeon-glue adhesive to provide extra reinforcement to this area. This was followed by an overall facing of Eltoline tissue and a from the back of the canvas. The stretcher, fitted with a polycarbonate panel, was placed over the reverse of the picture, and the strip-lining was then stapled to the stretcher. A further polycarbonate panel was slid under the front of the painting and taped around the back of the stretcher. The painting, stretched onto the stretcher and sandwiched between the two polycarbonate sheets, was then lifted off the table and turned faceup onto the table, which was covered with freshly siliconed Melinex.

The stretcher, the temporary strip-lining, and facings were all removed, and the losses in the painting were filled with Mowiol and chalk, tinted to match the color of the original gray priming. Following this, the painting was slid faceup onto the paneled stretcher, sandwiched between the polycarbonate panels and Melinex, and set aside while the lining canvas and vacuum envelope were prepared.

Preparation of the Lining Canvas

The lining canvas was prepared in an upper studio, as the ceiling height in the lining studio was too low to accommodate the wooden loom. The canvas—a single piece of linen with double warp and weft yarns—was stretched onto an expandable loom and wetted and prestretched three times to reduce the canvas's potential to shrink. The final wetting was done using a deacidifying solution of magnesium bicarbonate in distilled water with the intention of improving the longevity of the lining and its future removability (Ryder 1986).

The lining canvas was sized with one part Lascaux 375 to three parts mineral spirit, applied by brush. This not only provides a uniform appearance at the back after lining but also aids future reversibility by ensuring that more of the adhesive remains stuck to the lining canvas, rather than to the back of the original. Knots in the canvas were more readily removed (with scalpels) after the sizing, and both sides of the canvas were lightly sanded to give a smooth surface before a further six coats of Lascaux 375, diluted 1:1 in mineral spirit, were brushed onto one side of the canvas, with twenty-four hours drying time allowed between each coat. This produced an even adhesive layer that completely covered the canvas texture. The Lascaux 375 adhesive was not applied to the back of the painting, as that would have produced an overly strong bond between the two canvases and would impair the future removal of the lining.

The lining canvas was then removed from the loom and rolled onto a wooden roller, which was then taken to the lining studio.

Construction of the Vacuum Envelope

The vacuum envelope consisted of three lower sheets of thick Melinex taped together with good-quality cellophane tape and covered with overlapping sheets of silicon-coated Melinex, which were taped at the edges to the thick Melinex (fig. 8.5). The lining canvas was unrolled on top of the silicon-coated Melinex with the adhesive layer faceup, and the painting was then positioned on top of the lining adhesive.

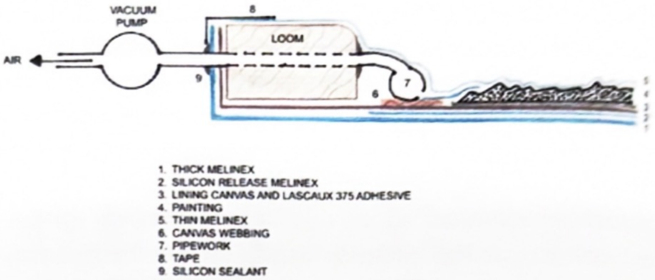

Figure 8.5 Diagram showing the construction of the vacuum envelope used to treat Van Dyck's *Equestrian Portrait of Charles I.* Image: National Gallery, London

The same loom used in the preparation of the lining canvas was positioned around the edges. The two long sides of the loom were reinforced with wooden strips to prevent it from bowing when the materials were stretched onto it, and holes were also drilled through the short sides of the loom to accommodate the tubing, which would later be connected to the two vacuum pumps (see fig. 8.5).

The lining canvas was first stretched onto the loom using staples. The thick Melinex was also stapled to the loom through a layer of tape to stop the Melinex from tearing, and the staples were then covered with more tape to prevent air leakage from within the envelope. The loom was lightly keyed out at the corners so that the lining canvas and Melinex were reasonably taut.

Strips of siliconed Melinex were taped around the edges of the picture to stop the exposed areas of Lascaux 375 at the edges of the painting from sticking to the top sheet of Melinex when the adhesive was heated (see fig. 8.5). This enabled the extraction of air from the central areas of the picture and ensured that the entire painting could be maintained under vacuum pressure throughout the lining process.

The air extraction system consisted of plastic plumbing pipes drilled with holes at regular intervals and placed around the edges of the picture and positioned on top of canvas webbing, which further aided the extraction of air (see fig. 8.5). The tubes connecting the pipework to the pumps were inserted through a hole at each end of the loom and sealed in place with silicon sealant.

The top sheet of thinner Melinex, three sheets taped together, was placed over the picture and taped to the top of the loom. Previously, the wooden keys in the corners had been covered with foam, and the edges of the loom rounded, in order to avoid any sharp edges inside the envelope that might tear the thin Melinex when under vacuum.

Apart from its size and the air extraction system, the construction of the envelope did not differ significantly from the one presented by Gerry Hedley, Stephen Hackney, and Alan Cummings at the Greenwich lining conference in 1974 (Hedley, Hackney, and Cummings 2003). As they discovered, the rigidity of the underlying thick Melinex is important in preventing areas of impasto and surface distortions in the painting from becoming "centered," or partially pushed out to the back of the lining when under vacuum.

The pumps were not fitted with pressure gauges, and three holes were drilled into the tubing at both ends to introduce air leakage and thereby a reduction in pressure. This number of holes was sufficient to allow the top layer of Melinex to be comfortably pushed away from the paint surface.

The Relining

A large Willard Multi-purpose Low Pressure Table with a surface area of 4 × 2 meters was used as the heat source. The painting, being larger than the table, had to be heated in two stages. Heating one half of the painting while the other remains cool presents a problem, however: as the first section is heated, the envelope and the materials inside it expand and can cause undulations between the heated and unheated areas. Several means were used to obviate this:

- The unheated section was warmed with domestic electric blankets covered with foil to retain the heat. This achieved a temperature of around 32°C on the picture surface.
- Four fan heaters were placed under the envelope pointing upward and toward the edge of the lining table. This gave a temperature of 38°C–40°C on the area of the painting above the edge of the table.
- A centimeter-thick strip of Plastazote foam was taped along the edge of the table to raise the envelope away from the tabletop and create an air gap that would reduce the temperature at this point.

The envelope was moved onto the Willard table with the half overhanging (not on the table) supported with adjustable props (fig. 8.6). For half an hour before the table was heated, the vacuum pumps were left running at full strength, with all the holes in the tubing covered with tape. This ensured that any air trapped between the lining canvas and painting was extracted.

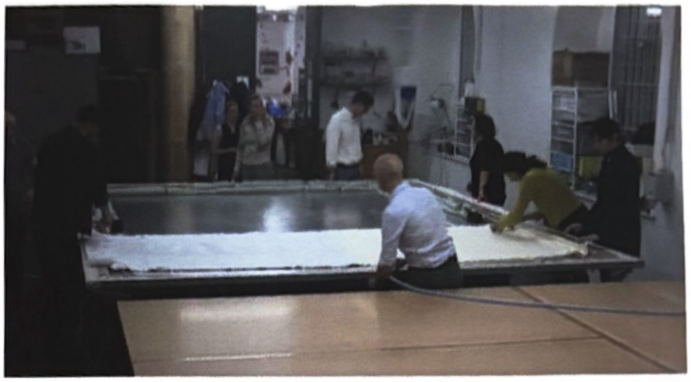

Figure 8.6 Relining of the Van Dyck painting inside a vacuum envelope using a Willard Multi-purpose Table as the heat source. Image: National Gallery, London

The holes in the tubing were then untaped and the pressure reduced. The table's heaters, set at 70°C, were switched on, and at around 45°C, the temperature at which the adhesive begins to soften, local areas of the painting were treated with hot spatulas to improve small remaining surface distortions. The temperature at the top surface was independently monitored with thermocouples, and once these had reached 68°C, the envelope was lifted off the table and the second half was then positioned, with a slight overlap between the two sections. The electric blankets were removed and the foil placed over the already heated section.

Despite the measures used to prevent undulations from occurring, these did begin to appear, but they disappeared instantly when the props at the unheated end were raised, increasing the air gap between the envelope and the edge of the table, and thereby reducing the temperature at this point.

Once the entire painting had been heated, it was carried, still under vacuum, to a large table, where it cooled within fifteen minutes. The envelope was dismantled, and the following day the painting was restretched onto its existing stretcher using copper tacks, and the keys were secured.

CONCLUSION

The treatment did much to improve the surface appearance of the painting by removing the lumps and undulations created by the 1952 wax relining and also provided a more durable support for the picture than had been previously achieved. Although improvements were made to the raised creases that were a result of Morrill's second relining, the flattened and moated areas of impasto remained unchanged. After the relining had been completed, the painting was retouched and revarnished before being returned to display in room 31 (fig. 8.7).

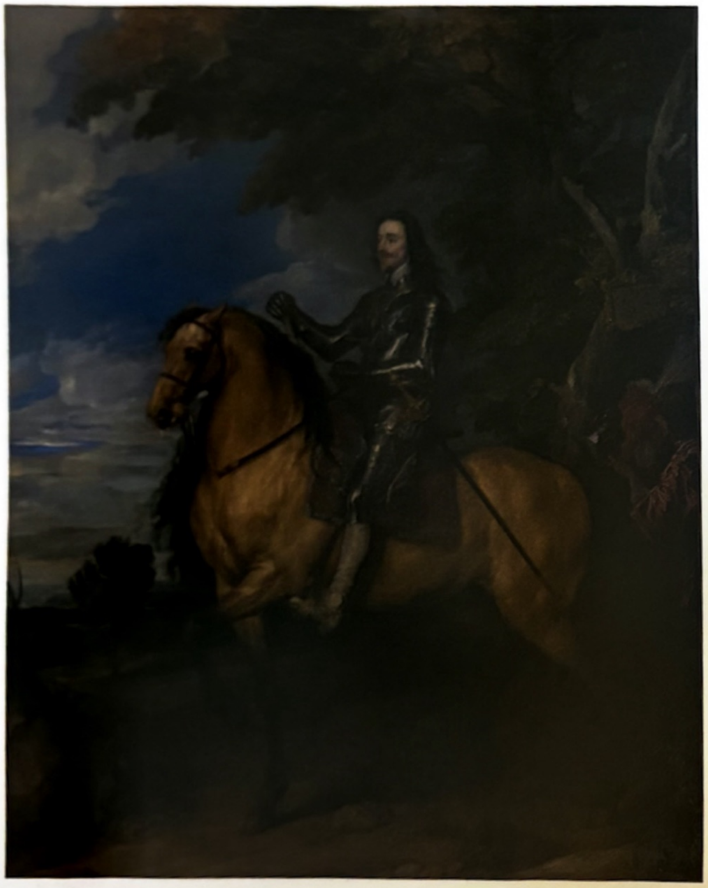

Figure 8.7 Van Dyck's *Equestrian Portrait of Charles I* after relining and restoration. Image: National Gallery, London

ACKNOWLEDGMENTS

The National Gallery is grateful to the Getty Foundation for its generous support of the relining of the Van Dyck, which enabled the participation of seven conservators from the United Kingdom and abroad. Thanks are also due to the participants: Gerrit Albertson (Metropolitan Museum, New York), Francesca Bettini (Opificio delle Pietre Dure, Florence), Eva and Lucia Martinez (Museo del Prado, Madrid), Luigi Orata (private conservator, Florence), Camille Polkownik (Hamilton Kerr Institute, Cambridge), and Lisette Vos (Rijksmuseum, Amsterdam), and all my colleagues in the Conservation Department who assisted at various times throughout the project, particularly Lynne Harrison and Juraj Grac.

APPENDIX: TREATMENT DETAILS

Materials

Eltoline tissue: long fibered 100% manila fibers with good wet strength

Resin 'W': Evo-Stik wood adhesive, Bostik Ltd., United Kingdom

Saatifil PES 120/41: Preservation Equipment Ltd., Diss, Norfolk IP22 4HQ, United Kingdom

Lascaux Heat-Seal Adhesive 375: A. P. Fitzpatrick Fine Art Materials, London E1 5QJ, United Kingdom

Linen lining canvas with double warp and weft threads available in 4.2 m roll widths: Claessens Canvas, 8790 Waregem, Belgium

Mowiol GE 4-86: polyvinyl alcohol, Kuraray Europe GmbH

Stabiltex: No longer commercially available

Recipes

Wax-resin facing adhesive made from dammar resin and beeswax: 340 g beeswax/1700 ml dammar varnish (454 g resin/280 ml mineral spirit)/850 ml mineral spirit

Wheat-starch facing adhesive made from 25 g wheat starch/100 ml distilled water/25 ml sturgeon glue (10% solution in distilled water)

Deacidifying solution of magnesium carbonate in distilled water: 8.8 g magnesium carbonate/1000 ml distilled water prepared in a domestic soda siphon in which two carbon dioxide capsules were discharged to form an aqueous solution of magnesium bicarbonate

Mowiol and chalk filler: 240 g Mowiol GE 4-86/1000 ml water with enough chalk and pigment to produce a stiff paste

9

Demystifying Mist-Lining

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Mist-lining was developed by Jos van Och at the Stichting Restauratie Atelier Limburg (SRAL) in Maastricht, the Netherlands, in the 1990s. It has since been used successfully to line numerous paintings, large and small, of different ages, conditions, and techniques. Pretreatments are used to solve distinct problems, leaving the action of lining solely to providing additional support. The mist-lining system avoids the use of heat, moisture, and high pressure and thus respects the integrity of the original structure and texture. Mist-lining provides an alternative, low-cost system to traditional or other modern lining techniques. Careful selection of lining support, the manner in which the lining adhesive is applied, and the means to set the bond differentiates this technique. The acrylic adhesive creates a "bridge" between the two canvases without impregnation. Choosing the right solvent for activation allows the acrylic adhesive to bond well to a wide variety of previously treated canvases, including wax-resin lined paintings. The bond has good shear resistance, though its peel force is lower. Delining of previously mist-lined canvases is therefore facilitated, allowing mist-lined canvases to be removed successfully, even over time.

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INTRODUCTION

Lining canvas paintings has ever been a contentious action. Many canvas paintings have been lined and at times relined. Age and condition have often not been prerequisites for implementing linings, as for a time it was seen as a preventative measure. Linings were intended to carry the load that the original damaged support could no longer bear, as well as solving a multitude of other structural issues, including consolidation and improvement of cupping and planar distortions. This often "one-stop" process was deemed long lasting, beneficial, and cost efficient. The type of lining carried out tended to be dependent on the training of the conservator-restorer, studio practice, and geographic location. Time has shown that the life span of linings is determinable, and the lining cycle continues.

The "moratorium" on lining called for after the 1974 Greenwich Conference on Comparative Lining Techniques (Villers 2003b) never materialized, but the idea encouraged conservators to think of other options for structural repair. Full linings fell out of fashion, and strip-lining as well as thread-by-thread tear mending became standard practice. However, these options cannot be used for severely structurally compromised canvas paintings—thus, full lining continues to be necessary. The mist-lining process is still a relatively new technique and not yet part of many conservators' toolkits. Familiarity with this process can expand the contemporary conservator's repertoire and provide one of a few ethical solutions for structural support.

The mist-lining process was invented and developed by Jos van Och in the 1990s at the Stichting Restauratie Atelier Limburg (SRAL) (Fife, van Och, and Harrison 2017; Seymour and van Och 2005; van Och and Hoppenbrouwers 2003). The term *mist-lining* was coined by SRAL in the early 2000s and is now used to denote the technique, system, and process. The mist-lining system has roots in developments in structural treatments for lining canvases initially presented in the 1970s by Gustav Berger and Vishwa R. Mehra and presented by both at the Greenwich conference in 1974 (Berger 1972a; Mehra 1975a; Mehra 1975b).

Mist-lining is a noninvasive lining technique that involves spraying minimal amounts of an acrylic dispersion resin onto an auxiliary canvas before adhering that canvas to the reverse of the original support, often without tension. This open adhesive network is regenerated from the dry state, eliminating moisture. Solvent vapors (or gentle heat) are used to swell and tackify the adhesive.[1] Bonding occurs under light pressure when the adhesive is activated. The system can be classified as a cold-lining method and forms a nap bond. The lining adhesive remains sandwiched between the two canvases with no impregnation of either textiles or decorative layers, which aids reversibility and negates any alteration of appearance.

MIST-LINING METHODOLOGY

The origins of mist-lining lie in the desire to find an ethical replacement for more invasive lining techniques. Conservators commit to following a code of ethics. These emphasize that cultural heritage should be preserved for future generations while respecting aesthetic, historic, and intangible significances, as well as maintaining physical integrity. Conservators should, thus, limit treatment to necessary actions and strive to use compatible, non-altering products, materials, and procedures. Treatments should not interfere with future actions, examination, or analysis, and should be reversible.[2] The nonimpregnating, easily reversible mist-lining system complies with this ethos.

The mist-lining process is not a stand-alone procedure and must be considered in relation to other treatments that will be carried out on the painting, either before or after lining. The mist-lining methodology requires each problem to be handled independently. Simply put, the issues presented by the painting are analyzed, and solutions to each specific situation are found and resolved independently of lining. The lining action is, thus, kept separate from other required treatments. This enables the process to be highly adaptable and tailored to the individual case.

Mist-lining is typically carried out after any reduction of planar distortions, overall treatment of the support, consolidation of paint layers, individual mending and/or strengthening of tears and holes, and removal of undesired superficial layers. Deformations are first flattened by prestretching the support and applying gentle and gradual lateral tension, often combined with humidification. Conversely, the mist-lining system will conform to any preexisting out-of-plane deformations and thus can be used to support (modern) canvas paintings devised with a more three-dimensional nature.

Consolidation of paint layers occurs as a separate step using an appropriate adhesive. Removal of varnish layers and overpaints is carried out prior to lining, though lining can be effectuated with any nonoriginal coatings left intact. Subsequent treatments often involve filling of paint losses, retouching, and revarnishing. After mist-lining, it is imperative to consider fully the implications of the choice of solvent for varnish application, or the use of heat to impress texture in fills, as both solvent exposure and heat will affect the lining adhesive. Some examples of pretreatments implemented prior to mist-lining are reported in the *Mist-Lining Handbook* (Seymour and Strombek 2022). Mist-lining has been a successful choice for paintings that have a past structural treatment legacy, whether lined with glue-paste or wax-resin adhesives or both. Research has been carried out showing that the sprayed acrylic adhesive adheres well to canvases impregnated with wax resin (Contreras 2015; Fischer 2002). This property enables the use of heat to be avoided on these thermo-sensitive structures.

The mist-lining process allows conservators to make the best choice for the needs of the individual canvas painting rather than using a standardized technique to solve all issues. The choice to use the mist-lining system, thus, comes at the initial stage of the decision-making process—when considering the treatment plan—although the commitment to using the system can be altered, if necessary, as treatment progresses. The order of treatments, therefore, needs to be fully considered before the plan is confirmed. Our philosophy is to leave options open as much as possible. Each step of the treatment process is thought through, taking into account the consequences for subsequent procedures and future behavior of materials inherent in the system. For this reason, the pretreatments prescribed have great importance.

The decision to use this system comes with a caveat. Expectations for results need to be tempered to accept surfaces that are not as "flat as a board" or linings that are not as "rigid as a plank." This system does not produce the same degree of surface finish and stiffness provided by traditional linings. The natural drape of the canvas and texture of paint layers will not be significantly altered during lining. Any out-of-plane texture or impasto (including cupping) that exists before lining will be maintained. Consolidation problems are not resolved. The key, as mentioned, is to treat these defects, as necessary, prior to lining and to accept a certain natural "aged" look. (This may mean taking a different approach to dealing with clients or owners of paintings.) Nor does the system provide a stiff lining support. Mist-lining moves away from the idea that the lining should carry all the stress within the laminate structure. Instead, a mist-lining provides "gentle" support to the original materials, helping to mitigate dimensional changes induced by climatic variations, but not preventing them.

These aspects of the system remain open to debate. No complete scientific study comparing mist-lining results to those of other lining systems has been carried out. This "new" approach thus remains unprovable. However, numerous paintings, large and small in scale and presenting a wide variety of past treatments and conditions, have been lined with this system. These have performed well over the last thirty years, so perhaps the "proof is in the pudding." Ongoing research aims to provide further insight and answers to these issues (Poulis, Seymour, and Mosleh 2020).

THE MIST-LINING PROCESS

As mentioned, the mist-lining technique uses an acrylic dispersion resin sprayed onto a prepared auxiliary textile support. The result is an open network, rather than a continuous layer of adhesive, which is allowed to dry on application. After the lining canvas is placed in position, the adhesive can be regenerated in situ with solvent vapors. Bonding occurs under low pressure without the use of heat or moisture. The system effects a nap-bond with no impregnation of the original textile or migration into the decorative layers. This aids reversibility and avoids any change in appearance. Delining can be effected by applying peel forces (sometimes after solvent exposure) with little or no adhesive remaining attached to the original textile.

The technique requires little equipment and is easy to set up in the studio or on site. The low-pressure envelope can easily be adapted to accommodate paintings of different sizes or orientations (horizontal or vertical). Linings have been effectively implemented on all sizes of paintings, including large, oversize formats.[3] Low-pressure tables can also be used, if a flatter lining surface is needed. Furthermore, the adhesive mixture and application process can be applied to effect strip-linings if a full lining is not desirable.

Canvas Selection and Preparation

Factors influencing the choice of lining canvas are the ability to develop a nap, flexibility versus rigidity (drape), responsiveness to humidity fluctuations, type of weave, and thickness of the canvas. The response rate of warp and weft threads to external conditions should be similar. Open-weave fabrics are preferred, as less tension is required to decrimp the fabric and to remount the painting. More importantly, solvent vapors can diffuse more readily through open-weave textiles so less solvent volume is required during activation.

A wide range of textiles has been used by the SRAL team over the years. Research into the mechanical properties of linen, polyester, and mixed-fiber textiles has been considered (Young and Jardine 2012). Choices are made on a case-by-case basis. The canvas requires a spun-yarn textile fabric, rather than a monofilament. Typically, open-weave lightweight natural linen fabrics or a fire-resistant lightweight spun-yarn polyester textile (Trevera CS) are used. Many other fabric types have also been experimented with and employed (Seymour and Strombek 2022).

The lining canvas may be tensioned prior to the application of the sprayed adhesive. Natural linen textiles are decrimped only if the weave is dense, as the necessity is less for open-weave textiles. The desired tension of the lining textile is dependent on numerous factors. The conservator should determine if the lining process will take place under tension or with either or both canvases in a free state. This decision may depend on logistics (size), the condition of the painting (first lining or relining), and future display (environmental factors). Tension is thus considered a variable in the process and cannot be quantified with a constant number; however, the tension applied when preparing the lining canvas should not be more than what will be required when remounting the painting. The aim is not to overstretch the adhesive when the lining is complete and to effect in an undisturbed point-to-point bond between the two canvases.

The size of the original support (including tacking margins) is masked out on the lining canvas to ensure that the edges of the lining fabric are not coated with adhesive. The surface of the stretched lining canvas is prepared by enhancing the nap. The yarn is disrupted to encourage fibers to protrude from the surface. Nap fibers are fluffed up using sandpaper worked gently in the same directions as the weave. The yarn should not be broken. Care is taken not to disturb the napped surface before spraying on the adhesive.

Interleaf textiles can be inserted as required to provide enhanced local (to support tears or holes) or overall stiffness. Nonwoven polyester or woven glass-fiber interleafs (adhered prior to lining with either Plextol mixtures or Beva 371 film) are typically used at SRAL. These will mitigate the return of viscoelastic, out-of-plane deformations.

The Adhesive

Currently, two methacrylic ester-acrylic ester copolymer dispersions are mixed to obtain desired performance stiffness and solubility characteristics. Plextol D 540 and Dispersion K 360 (adjusted to pH 7) were used in a 30:70 ratio, but other formulations are being further investigated due to the discontinuation of Plextol D 540. The manufacturer of Plextol (Synthomer) has recommended as a substitute Plextol D 512.[4] This and other alternatives (Plextol D 498 and Plextol B 500) are being tested to compare results at Delft University of Technology (TU Delft) (Poulis, Seymour, and Mosleh 2020).[5]

A high-volume, low-pressure (HVLP) compressed-air spray gun is used to spray the adhesive onto the canvas in a fine mist. The spray mist only encapsulates the raised nap and does not impregnate the lining fabric or create a continuous coating. As only the nap is coated, the mechanical-physical properties of the canvas are unchanged; it remains flexible and able to conform to the drape and morphology dictated by the original canvas.

The optimum result is achieved when the adhesive is sprayed from different angles in more than one layer. The aim is to use as little adhesive as possible, something that is currently judged through experience. The coating should remain open and "fluffy" so as to allow the solvent vapors easy access. A thinner layer of adhesive will react more quickly to the solvent vapors and will need less pressure to create a bond, but the bond achieved will be more resistant if the adhesive layer is more substantial. It is, however, never the aim to have a thick layer of adhesive! The ultimate thickness of the sprayed adhesive layer is considered one of the key variables of the system. We suggest those new to the system practice these decision-making processes on mock-ups to gain insight into such variables. Figures 9.1 and 9.2 show an example of the dried adhesive layer applied to an open-woven linen canvas.

Figure 9.1 Close-up of the open-network sprayed lining adhesive. Image: SRAL

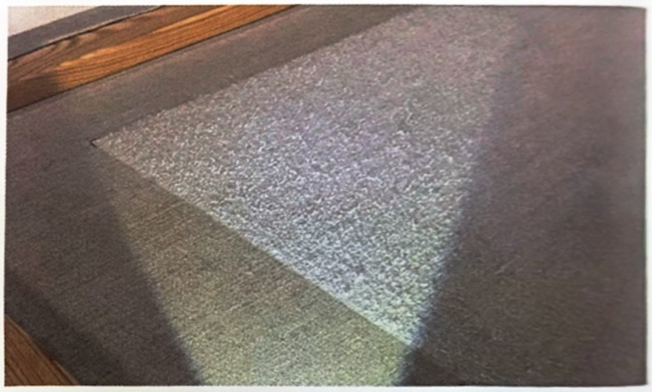


Figure 9.2 An open-weave linen canvas sprayed with an acrylic dispersion adhesive. Note the masked-out area, which is the exact dimensions of the painting that will be lined. Image: SRAL

The sprayed acqueous adhesive is allowed to dry before lining occurs. The two canvases are brought together before a subsequent bond is effected within a low-pressure envelope. The original canvas is carefully positioned on the lining canvas in contact with the sprayed area. Smaller paintings can be lined faceup with the lining canvas either loomed or untensioned, while larger paintings are typically lined without being tensioned and facedown. In the latter case, the lining canvas is often rolled into position over the exposed reverse of the original. It is imperative that placement is carried out carefully and precisely, so as not to flatten the fluffed, open network of the adhesive and to ensure that the weave of the lining canvas aligns with that of the original. Dragging the original over the sprayed adhesive surface will deform the adhesive surface and compress it into a continuous coating.

The Low-Pressure Envelope

The low-pressure envelope consists of two differing thicknesses of high-density polyethylene (HDPE) plastic sheeting and a ring of perforated pipes connected to a centrifugal fan (or vacuum cleaner) (fig. 9.3). Both plastic sheets should be solvent (and heat) resistant. The plastic sheeting is typically sourced at local building merchants. The thicker plastic sheet can be stretched to a working frame that is larger than the lining canvas or taped to a flat surface such as a table or floor. The thinner, unstretched plastic sheet should be flexible enough to accommodate surface topography (e.g., impasto, cupping). In some cases, the setup can be reversed.

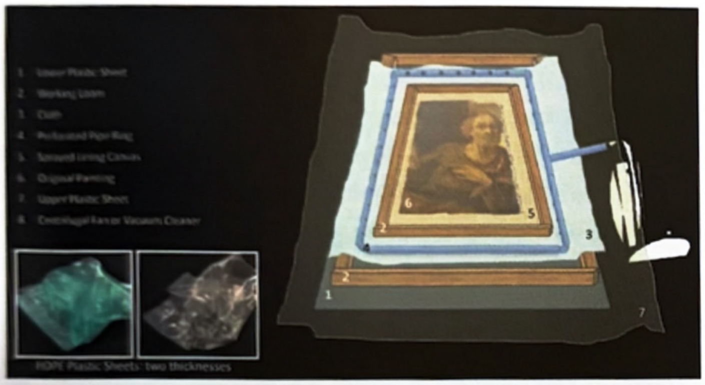


Figure 9.3 Schematic view of the setup for the low-pressure envelope. Image: Kate Seymour

The design of the low-pressure envelope is another key variable of this adaptive system. Varying the thickness and tension of the plastic sheeting will modify the pressure exerted. The flexibility of the plastic sheeting allows an even pressure to be applied over the whole surface area as the plastic conforms to the topography of the structure within the low-pressure envelope. Slight deformations in the canvas can, however, be manipulated, but the system does not exert sufficient pressure to push severe deformations into plane. A stiffer sheet of plastic (such as Melinex) would exert pressure on high points and the force exerted would be imposed on a smaller area. Using a too-stiff membrane could potentially cause moating or even flatten impastos; it could also push out-of-plane structures, such as seams, forward.

Air is extracted from the low-pressure envelope using a ring of perforated pipes (diameter about 2 cm). Typically PVC pipes, intended to house electrical wires in walls, are used. These are sourced from local building merchants. Other improvised versions could be utilized, such as garden hosepipes or washing machine hose. The tubes should not deform when air is extracted. Lengths of up to 3 meters can be bought and modified to the desired size. Connection pieces make it possible to extend beyond this dimension and connect at the corners. The ring should be a good 20–30 centimeters wider than the (loomed) lining canvas. Both plastic sheets used for the envelope should be larger than the ring. Holes are drilled into one side of the pipes at regular intervals. When assembled, all corners and joints are taped together to ensure the ring maintains its shape and does not disconnect during lining. A T-connector is used to attach the ring to the centrifugal fan. When placed in the envelope, the pipes are covered with a textile "sock" to ensure that the plastic sheeting is not drawn into the holes.

Air is extracted from the center of the envelope by including a piece of cloth slightly larger than the ring system. This is called a "breather." It is typically placed on top of the stiffer membrane. Note that there should also be soft material placed under the envelope, outside the system, to ensure the envelope is floating and that, if punctured, it will not be sucked down to the flat surface, which would induce excess pressure during lining.

When the centrifugal fan is turned on, air is extracted from between the two plastic membranes evenly. Sharp edges (e.g., working loom members) should be padded with cloth coverings. These also aid in the extraction of air from the center of the envelope to the ring system. Thin nonwoven fabrics can also be placed over the paint surface if desired; however, these stop the upper plastic membrane from following the morphology of the surface and may diminish the bond achieved. The exact conformation to the surfaces (upper paint and lower textile) by the plastic sheets permits a point-to-point bonding at a low, even pressure.

Although the low-pressure envelope is used in the lining process, it can also be used for a variety of other conservation treatments. Further information on the materials used is provided in the *Mist-Lining Handbook* (Seymour and Strombek 2022). We advise some experimentation prior to determining the setup for the low-pressure envelope.

Bond Formation

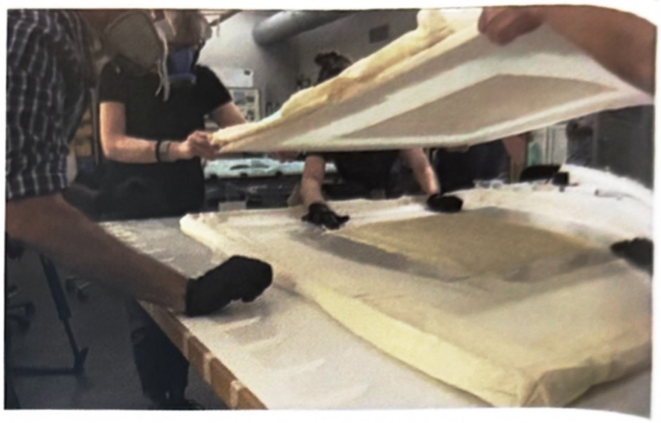
As opposed to a continuous coating, when dried the open adhesive network can effect a light bond with a relatively small amount of adhesive. A dried, thick, continuous (stiff) coating of an adhesive will need to deform or soften in order to uniformly connect the two undulating surfaces. In this case, heat and high pressure can expedite and ensure a good bond, but often at the expense of paint modification and impregnation of nonoriginal materials into the original textile and decorative layers. In the mist-lining system, the "fluffy" adhesive layer has a volume that accommodates the distance between the two woven textiles. During lining, gentle pressure is sufficient to ensure that the two canvases remain connected while the bond is being formed.

The adhesive is reactivated in situ using solvent vapors. Solvent exposure induces swelling, allowing the adhesive to regenerate and become tacky. The volume of solvent vapors, inserted into the envelope, required to regenerate the adhesive is carefully calculated to ensure that the adhesive swells and becomes sticky but does not dissolve, ensuring that the adhesive remains between the lining and the original canvas. Solvent selection is dependent upon a number of factors, including the sensitivity of paint and varnish layers, the condition of the reverse of the original support, any remnants of previous lining adhesives, and, of course, the solubility parameters of the adhesive. Acrylic dispersions are sensitive to a range of solvents, including alcohols and aromatic hydrocarbons.[6] Mixtures of these can also be considered. The choice of solvent(s), duration of exposure to solvent vapors, and the pressure exerted within the low-pressure envelope will affect the bond strength achieved and are considered variables in this system.

Testing ensures that the best solvent is selected. We recommend using smaller sections, or swatches, of a representative lining canvas sprayed with a similar amount of adhesive to test for an effective representative bond. Swatches are placed on the reverse of the original and exposed to different preselected solvent vapors for the same amount of time. The sections are left under weight until the solvent has evaporated, and then each is peeled away to evaluate the effectiveness of the bond. Experience builds an expectation of results, but tests ensure a better understanding of the individual variables that can be implemented for particular cases.

EFFECTING A MIST-LINING

The lining is carried out within the low-pressure envelope (fig. 9.4). First, the solvent vapors are introduced into the envelope using a "solvent-delivery cloth"—typically, an open-weave cotton cheesecloth. The ability of the solvent-delivery cloth to absorb the solvents used will dictate the volume of solvent that is needed; the volume used at SRAL is 60 ml of solvent per square meter of cheesecloth. The cheesecloth should be slightly larger than the area of sprayed adhesive, as it will shrink slightly as the fluid solvent is absorbed.



https://vimeo.com/762363049/f22edb5063

Figure 9.4 Video showing the mist-lining process. Video: SRAL

The solvent-delivery cloth is rolled up and encapsulated in plastic (clingfilm/Saran wrap) before the solvent is introduced. The solvent is injected into the package using a needle and syringe. Sufficient time must be allowed before placing the solvent-delivery cloth in the envelope for the solvent to spread evenly throughout the cloth. When the solvent has evenly dampened the solvent-delivery cloth and the lining setup is established, the cloth is rolled out inside the envelope, placed at the reverse of the lining canvas, as can be seen in figure 9.5. Placing the cloth in the envelope and rolling it out inside the envelope should be practiced, prior to the addition of the solvents, until it can be done quickly enough that solvent is not lost through evaporation (during the application process).

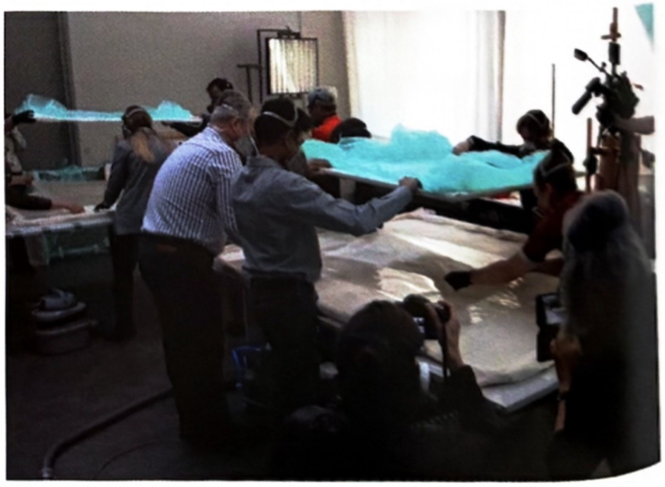


Figure 9.5 Mist-Lining Workshop trainees practicing placing the solvent-delivery cloth to reactivate the lining adhesive. Image: Joanna Strombek

The solvent vapors, thus delivered, defuse through the lining fabric to the open adhesive network. Once the adhesive is tacky (but not dissolved), the solvent-delivery cloth is removed; typically, this takes between ten and twenty minutes. Air is extracted from the envelope to expedite the activation time, but continual pressure is not necessary at this stage. The solvent-delivery cloth should be replaced with a dry cloth to facilitate solvent evaporation during bond formation.

Once the solvent-delivery cloth has been removed, the air is extracted from the low-pressure envelope. This causes the two canvases to be drawn together and the reactivated (thin) adhesive spray coating can bridge the distance between the two. Pressure is maintained until the majority of solvent vapors have evaporated and the adhesive is reset. The amount of pressure in the envelope is determined by the degree of air extracted by the centrifugal fan and the thickness/stiffness of the plastic sheeting. Typically, values of 90 mbar are reached and maintained for about sixty to ninety minutes. For safety reasons, as solvent vapors are being passed through an electrical motor, an attendant should be present at all times during the lining. The risk of sparks igniting dust particles within the motor should be prevented by using the motor exclusively for air extraction. Air exchange values can be used to reduce risk.

We recommend that conservators experiment and become comfortable with the system variables before undertaking a mist-lining. Results are impressive (figs. 9.6, 9.7). Aspects to consider are pretreatments, thickness of the adhesive layer, the type of solvents and lining canvas selected, and the setup of the envelope.

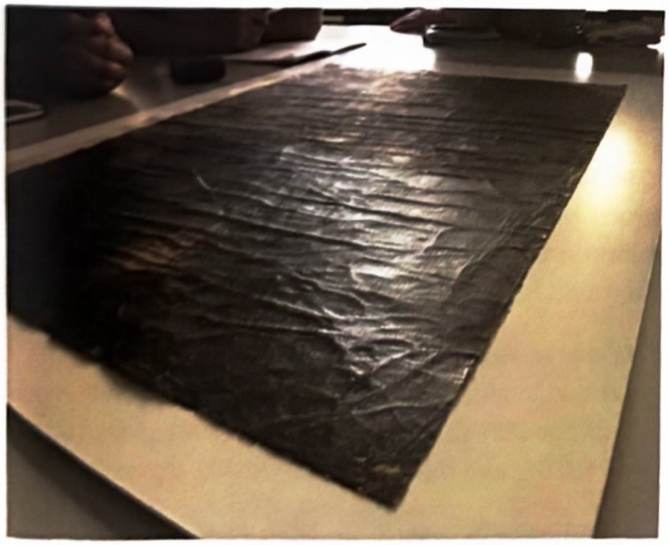


Figure 9.6 Deaccessioned painting prior to lining. Note that the out-of-plane deformations are mitigated prior to lining using gentle tension and controlled humidification. Image: SRAL

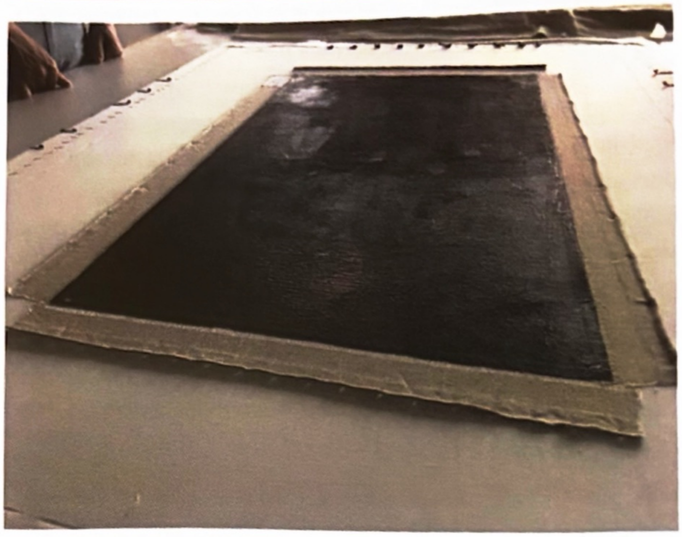


Figure 9.7 The deaccessioned painting shown in figure 9.6 after lining. The strip-linings added to apply tension prior to lining were kept in situ. The lined painting is still mounted on the temporary working loom. Note that the raised horizontal deformations are reduced, but the craquelure pattern is still evident. Image: SRAL

MIST-LINING DISSEMINATION

The SRAL team has imparted their knowledge and experiences of the mist-lining system to the wider conservation field over the years (see the appendix for a chronology of workshops and conferences disseminating the mist-lining system). Students studying conservation in the Netherlands have been instructed in the system since the early 1990s. International interns, fellows, and junior conservators working at SRAL over the past thirty years have all used the system. Papers have been written describing it, and presentations have been given at conferences (see Barbosa et al. and Brandt and Volbracht in this publication; Costantini 2013; Iaccarino Idelson and Garofalo 2019; Ruuben and Robbins 2011). Dissemination has had successes and failures and has led to further modifications in the system. The expertise of the system still remains largely in-house at SRAL, however, and the use of this relatively new system is not widespread. Because the system is adaptive and tailored to the needs of the painting, it is full of variables that may be difficult to grasp if not encountered in practice. Thus, confidence in considering this noninvasive and gentle approach to the structural repair of canvases may be lacking in many conservators less familiar with the system.

In 2019, with the generous support of the Getty Foundation's Conserving Canvas initiative, SRAL organized a Mist-Lining Workshop to further disseminate this technique and share our experiences.[7] The aim was to provide midcareer conservators from different world regions with hands-on experience in this alternative option for the structural repair of canvas paintings. At the same time, this global group also brought new thoughts and inspired further adaptations and developments of the mist-lining system (Nadeau et al. 2020). The workshop was documented in film and print. The video, produced by Bigeye Productions, can be viewed on YouTube for further insight.[8] The resulting *Mist-Lining Handbook* (Seymour and Strombek 2022) provides a valuable resource to the field. It is full of information on case studies, material information, and sources. Once practiced, the mist-lining system's variables become something that the conservator can use to tailor treatment to the particular needs of each case. The materials and equipment needed are low cost and relatively easy to source locally. It is hoped that these resources will give this viable system new traction as a treatment option.

CONCLUSION

The mist-lining system remains frequently used at SRAL. A numerical quantification of paintings treated with this system has not been carried out. However, it is safe to say that over the past thirty years, some hundreds of paintings belonging to local, national, and international collections have been treated by the SRAL team using this process. To date, none of those so treated have been returned due to failure of the lining. This body of work provides empirical confirmation of the success of the system. Of course, failures—or rather, disappointments—have occurred. These setbacks are typically evident immediately after lining, before the artwork is returned to its collection, and thus can be resolved immediately. Reflecting on these complications provides learning lessons for the SRAL team and encourages further developments or adaptations of the system.

Conservation ethics have shifted over the past decades toward a minimalist approach and avoidance of invasive treatments. The change in ethos to the structural repair of canvases allows the conservator to identify and find solutions to separate problems presented by the painting. Lining has become, with the mist-lining system, a custom action. There are, of course, drawbacks to lining with this system, such as covering the original canvas from view and using solvent vapors to regenerate the lining adhesive, because those vapors permeate throughout the painting structure. However, the choice of adhesive and its relatively long-term chemical stability mean that the adhesive bond can be reversed in the future. The original reverse of the canvas can thus be regained, if necessary, as the adhesive remains primarily on the lining canvas when delining.

The idea that the original canvas will never be the same again after a lining is carried out can now be left behind. The mist-lining system is noninvasive and can provide additional support for canvases without changing the stiffness of the original canvas and without influencing the appearance or saturation of the paint layers. While this process may not be the only modern solution to resolve this new way of thinking, it is an effective and versatile technique that has been used successfully for the last thirty years at SRAL and elsewhere to line a vast number of damaged paintings—and to reline paintings previously lined with glue-paste or wax-resin adhesives.

APPENDIX: CHRONOLOGY OF WORKSHOPS AND CONFERENCES DISSEMINATING THE MIST-LINING SYSTEM

1995–2006: Annual workshops for SRAL post-master's students

2006–20: Biannual workshops for postgraduate University of Amsterdam students

2007–8: Workshop and treatment of Hubert Vos's *Empress Cixi* at the Summer Palace, Beijing

2008: Workshop at Academy of Fine Arts, Dresden

2010: International symposium and workshop on lining techniques at SRAL

2010: "Current Practice and Recent Developments in the Structural Conservation of Paintings on Canvas Supports." ICOM-CC Paintings Working Group workshop at Metropolia University of Applied Sciences, Helsinki

2011: Ripping Yarns: Traditions and Advances in the Structural Repair of Canvas Paintings, British Association of Paintings Conservator-Restorers conference at the Courtauld Institute of Art, London

2011–14: Workshops at SRAL for students from the Courtauld Institute, London (2011); Hamilton Kerr Institute, Cambridge (2012); École Supérieure des Arts, Saint-Luc, Liege (2013); and New University (NOVA), Lisbon (2014)

2012: Glue-Paste Linings: Tradition, Performance and Stability, conference at Thyssen-Bornemisza Museum, Madrid

2015–18: Workshops for professions at M. A. Vrubel Museum, Omsk (2015); Indira Gandhi National Centre for the Arts, New Delhi (2016); Indian National Trust for Art and Cultural Heritage, Kolkata (2016); the State Tretyakov Gallery, Moscow (2018); and Brera Academy of Fiine Art, Arcore, Milan (2022)

2019–23: Getty Foundation, Conserving Canvas initiative, Mist-Lining Workshop (2019); Pilot Virtual Online Mist-Lining Workshop (2021); and Regional Mist-Lining Workshop (2023)

NOTES

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1. Acrylic adhesives are thermoplastic. Thus, dependant on the Tg, gentle heat (about 50°C) is also sufficient to tackify the dry adhesive and create a bond.
2. European Confederation of Conservator-Restorers' Organisations (E.C.C.O.), "Professional Guidelines I: The Profession" (2002), https://www.ecco-eu.org/wp-content/uploads/2021/03/ECCO_professional_guidelines_I.pdf; "Professional Guidelines II: Code of Ethics" (2003): https://www.ecco-eu.org/wp-content/uploads/2021/03/ECCO_professional_guidelines_II.pdf.
3. *Panorama Mesdag* project (1986–96). The *Panorama* was painted by Hendrik Willem Mesdag and workshop in 1881; it is 14.70 m high × 114.70 m in circumference (van der Donk, de Herder, and van Lier 1996). See also Panorama Mesdag Geschiedenis en restauratie van een schilderij zonder grenzen: https://www.npo.nl/close-up/11-07-2015/AT_2037854. While not technically a mist-lining, the Beva 371 lining adhesive was flocked and the heat-activated bond was set using a low-pressure envelope developed by Jos van Och, and is therefore one of the projects considered evolutionary in developing the mist-lining system. This remains the largest known painting lined (vertically) in situ.
4. Email correspondence between Kate Seymour and Thomas Bernhofer, technical service manager, Coatings, SBU Functional Solutions, Synthomer, March 28, 2018. See also http://www.synthomer.com.
5. Until recently, tests at SRAL have been empirical in nature, conducted on mock-ups or historical material (such as old, removed lining canvases or deaccessioned paintings). The lining process and specifications have been adjusted and tested for specific cases. Samples were analyzed between 2014 and 2017 by Dr. J. A. (Hans) Poulis (director of the Adhesion Institute, TU Delft) and a team of interns at TU Delft, Aerospace Division as well as students from the University of Amsterdam as part of master's thesis research. See Poulis, Seymour, and Mosleh 2020.
6. The toxicity of the solvents can also be considered. Personal protective equipment (PPE) can be used to safely work with toxic solvents. Environmental factors and sustainability issues may also influence solvent selection.
7. To date, two more workshops have been organized under the auspices of the Getty Foundation's Conserving Canvas initiative since the first workshop.
8. "De-Mystifying Mist-Lining," instructional and documentary movie about the mist-lining system (2020), produced by Benjamin Brack and Akkie Brack-Sewalt, Big Eye Productions, https://www.youtube.com/watch?v=jU-QwEfYt44&feature=emb_title.

VII

Conserving Modern and Contemporary Art

The Structural Treatment of Modern and Contemporary Canvas Paintings: Changing Approaches and Considerations

Mary H. Gridley, Partner, Art Conservation Solutions LLC, New York

Changing priorities about the structural treatment of modern and contemporary paintings on canvas mirror the general trend in conservation toward localized or minimal interventions and reflect the lack of consensus among stakeholders—including the artists themselves—about an acceptable degree of aging in these recently made works. Surface perfection rarely coexists with age-related authenticity. While the use of unconventional materials or techniques in an artwork can complicate treatment, some commonly used modern artists materials, such as acrylic paints and grounds, can be exploited for our benefit during treatment. The unique demands of these paintings and our struggle to find suitable and successful treatments for them have generated a welcome increase in scientific research into modern materials as well as specialized training for emerging conservators.

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INTRODUCTION

As a conservator in private practice in New York who specializes in recently created artworks, I have spent a great deal of the last twenty-five years performing structural repairs on canvas paintings, absorbing and adapting to the ever-evolving techniques and goals of these treatments.

Modern and contemporary art is loosely defined as anything made in the last 75 to 125 years, a span that embraces many different styles and "schools." But for practical purposes, in paintings conservation we think of it as starting with the Abstract Expressionist era, in the 1950s, when artists' use of nontraditional materials and painting methods dramatically increased. Paintings created with non-artist-grade supports or paint, with unusual media such as chewing gum or molasses, or those with Minimalist surfaces that readily show every damage can be difficult to treat. Monochromatic paintings, a perennial lure for modern artists, in which the subtleties of the surface are paramount, can be particularly challenging.

Works that are intended to be displayed unframed, unglazed, and unvarnished are vulnerable to damage from handling, travel, and installation. Hence, while conservators of these works are rarely faced with failing fabric supports or extreme cupping, they are confronted with impact cracks, tears, and deformations, some of which may be exacerbated by poor materials or inadequate structural supports.

While monochromatic or unconventional surfaces may be challenging to maintain during a structural treatment, some of the other material components of these works are more resilient and less degraded than those found in older, more traditional paintings, greatly improving the odds for successful treatment. Cotton duck, widely used by American artists for the last seventy years, behaves differently than linen. The common use of acrylic gesso and sizing, which retain malleability and are quite responsive to moisture, temperature, and solvents, provide layers that can be exploited in the flattening of cracks and cupping.

Over the last six decades in both private practice and institutional conservation labs, the structural treatment of twentieth- and twenty-first-century canvas paintings has mirrored that of older paintings, moving away from lining as localized solutions became more popular. Conservators have promoted the embrace of minimal intervention, as well as respect for authentic and historical elements and meanings of the artwork, to private collectors, dealers, and artists. *Authenticity* in this context describes a number of qualities of an artwork other than its outward face. Tangible examples include normally unseen elements, such as stretchers, inscriptions, old tacking holes, studio handling marks, labels, and provenance. More intangible and subjective aspects are age-related patination or historical associations independent of the imagery. The relative value of all these types of authenticity varies widely by time and place and is a reflection of the concerns of the larger culture.

Actual treatments I have carried out are often a compromise between returning the surface of a work close to its original, unblemished state and acknowledging or embracing its evidence of authenticity and age. Many of these works have never been treated, so the treatment methods and materials employed must have an eye to future ramifications.

The rising popularity of contemporary art has greatly impacted the conservation world. There is a fast-growing body of research into modern materials and artists' techniques. The proliferation of smaller institutions devoted to contemporary art collections feeds the demand for materials and technical research, as well as for care and treatment of this type of painting, and has spurred more specialized training in conservation degree programs. Graduates have spread out across the globe to staff institutions and the private studios devoted solely to treatment and care of these works.

CHANGING CONSERVATION PRIORITIES

In the private sector, the goal of most treatments is to make an artwork exhibitable—and, depending on the stakeholders, salable. For modern and contemporary paintings, which are still transitioning from brand new to antique, this can mean different things for different artists, for different genres, and for different owners: there is no unilateral agreement on what levels of damage are considered acceptable for display. While there is an obvious desire for a legible surface that clearly demonstrates the artist's aesthetic intent, there are also varying notions about whether and how to value signs of age or history. Institutions tend to tolerate more evidence of age than the private sector, where these artworks have not only an aesthetic and historic value but also perhaps a significant financial one.

Treatment choices not only depend on what is possible but also can be driven by what is deemed most important for a given artwork by a given collector. If an owner is anxious to obliterate any signs of damage or aging, no cracks are left untreated. Another may want only the eye-catching, prominently placed impact cracks treated, but not those at the turnover edges, and for a third, a moderately cracked and aged paint film is an appropriate expression of the age and history of the object itself. Contemporary artists themselves have strong opinions about what degree of damage is acceptable in their work. In my experience, if asked, they generally say they want it to look "perfect" and are often willing to repair or remake it themselves if it cannot be successfully conserved—an outcome that can open up Pandora's box. Decisions about how much to treat and what to prioritize are not specific to modern and contemporary art, of course, but have been more open for discussion as the conservation field has evolved from the scattered and relatively isolated group of artist/restorers of old to the degree-trained conservators of today.

What the art world now thinks of as "blue chip" contemporary art was initially collected and promoted by small groups of enthusiasts and was not widely sought after. It was not of very high value compared to works of Cubism or Impressionism or the old masters, for example. Only a few conservators—all of them apprentice-trained or self-taught—performed treatment exclusively on these works. In New York, Daniel Goldreyer, Orrin Riley, Jean Volkmer, and Margaret Watherston all wrestled with the unique demands of modern and contemporary paintings, adapting old techniques or inventing new ones.[1] Their clients were often the artists themselves, which allowed for influential and sometimes controversial. The apprentice system was alive and well during this period, and many of my colleagues today trained with one or more of these individuals.

Naturally enough, those conservators used the tried-and-true structural repair techniques that succeeded on older paintings. They also enthusiastically embraced the new equipment, lining adhesives, and supports adopted and developed in the 1950s, 1960s, and 1970s, many of which were introduced at the 1974 Conference on Comparative Lining Techniques in Greenwich. These included Gustav Berger's Beva 371 adhesive (and the subsequent film form), flocked polyvinyl acetate (PVA) adhesive, nap-bond adhesives, fiberglass solid and fabric supports, polyester sailcloth fabric, stiff Mylar interleaves, and low-pressure hot tables. I have seen examples of most of these lining types on paintings that have come through the studio. Some have been very successful, some less so, but their application to modern and contemporary paintings is problematic for some collectors and dealers: there is a perception that a lined contemporary painting is somehow lesser. This could be a genuine aesthetic problem, for example, weave interference or other subtle alterations to the surface created by pressure or heat during the lining process.

More often, it is the verso that is the problem. Paintings lined using heavy Mylar are a case in point. Even if the lining has successfully brought the cracks or tears into plane, the very shiny plastic appearance of the Mylar on the verso is an inescapable reminder that a painting has had fairly extensive conservation treatment. Localized repair of structural damage, while often much more labor intensive and therefore more expensive than a global treatment like lining, satisfies two criteria I think are important: retreatability and a light touch, both of which leave the door open to better future solutions for these young paintings.

The search for better methods and materials for structural treatments in the years leading up to Greenwich was an acknowledgment that lining treatments corrected some types of damage but could also create new ones. After Greenwich, this realization slowly manifested as an ethical dilemma: Was lining too aggressive? *Should* the many individual issues a lining could resolve—flaking, distortions, cupping, tears, weakening fabric—be dealt with all at once? Or would it be better to deal with them separately and perhaps delay a lining treatment? What began in Greenwich as an exciting, hopeful exchange of new research and techniques on improvements in the structural treatment of canvas paintings was flipped on its head by the realization that perhaps it was not the *method* of lining, but the *act* of lining that needed to be reevaluated (Percival-Prescott 2003b). Subsequently, a period of reflection set in, and many conservators began to pull away from global treatments, opting for more localized, targeted treatments instead.

The ascendancy of "minimal intervention," as this approach came to be called, had a substantial effect on the continued prevalence of lining. When I was a graduate student at the Courtauld Institute of Art between 1988 and 1991, structural conservation of canvas paintings in London (and perhaps elsewhere) was at a crossroads. Although students were instructed in both structural and cosmetic treatments, there was a separation between the two in the real world at the time—an acknowledgment that only specialized knowledge and experience could confer mastery in one or the other. There were still private studios in London where pictures were sent to be lined, and the National Gallery of London maintained a separate studio and conservation staff that dealt only with structural work. The ample research into better methods, materials, and equipment in the 1970s and 1980s spurred many conservation studios to procure the new equipment needed to offer lining treatments to their clientele. But the equal and opposite move away from global interventions meant these tables were used less and less, until in many studios they became simply flat surfaces on which to do other kinds of work (Hedley and Villers 1993; Stoner 1994). In the first studio where I worked when I returned to New York in 1994, the lining table was used only for moisture and flattening treatments. I have not worked with a lining table since, using instead a portable suction platen or steel weights when flattening was necessary.

This shift toward separate and/or staggered treatments has become deeply embedded in the current conservation culture, and we have passed that philosophy on to a wider public. Conservation as a whole has a much higher profile today thanks to targeted exhibitions, public-facing conservation labs in museums, and treatments carried out in public galleries. One change I have observed over the last few decades is that our more sophisticated clients actually notice past structural treatments and have opinions about them, which is a testament to how much more mainstream conservation and discussion of condition has become. This is in stark contrast to what George Stout, one of the founders of science- and museum-based conservation in America, described as the "contempt for concern about condition" prevalent in his early years in the field (Stoner 2005). Historically, the importance of an artwork was confined to its surface imagery and art historical importance; whether the painting had had conservation treatment—even treatment that radically altered the surface—was not considered relevant.

TREATMENTS ON MODERN AND CONTEMPORARY PAINTINGS

Lining and Patching

Given the practical and existential difficulties of lining, it is not surprising that some examples of early linings of modern and contemporary paintings that have passed through our studio provide cautionary tales. This is particularly true for Minimalist paintings, which have the infuriating characteristics (to the conservator, at least) of being the most in need of structural intervention when cracks appear and having the least tolerance for any intervention. Given the extremely subtle nature of the aesthetics of these paintings, some examples of early linings we have seen exhibit changes to the paint film that we are anxious to avoid repeating, such as locking cracks in place with thick layers of adhesives and auxiliary supports, thus prohibiting access to the reverse. One previously treated, multipanel Minimalist painting I worked on had numerous impact cracks on all five canvases. Two of the panels were unlined while the other three had been lined with thickly flocked PVA. While the cracks in the unlined elements were improved with local flattening treatments to the reverse, the PVA on the other three could not be safely removed, so the cracks could not be retreated.

Although I have seen old linings—of all varieties—that have worked well and remain sturdy, this is not always the case. A great deal of the success relies on the experience of the practitioner. Glue-paste linings in particular seem to require a vast amount of particularized knowledge and skill. On a Minimalist painting, they can be wonderfully successful, but they can also result in weave interference due to lining pressure and small distortions caused by uneven adhesive application or inherent faults in the canvas weave.

Wax-resin and Beva linings are less stiff and unyielding, but that can create problems as well, such as spotty delamination between the original and lining canvases due either to an initial, uneven heat application or to eventual degradation of the adhesive (figs. 38.1, 38.2). The inherent flexibility of these adhesives—so useful in other contexts—is often no match for the paint film's strong need to equilibrate forces around existing cracks, leading to their reappearance over the long term. I have seen wax-resin linings change the gloss of a surface or darken with time, throwing off the balance of light and dark in the composition.

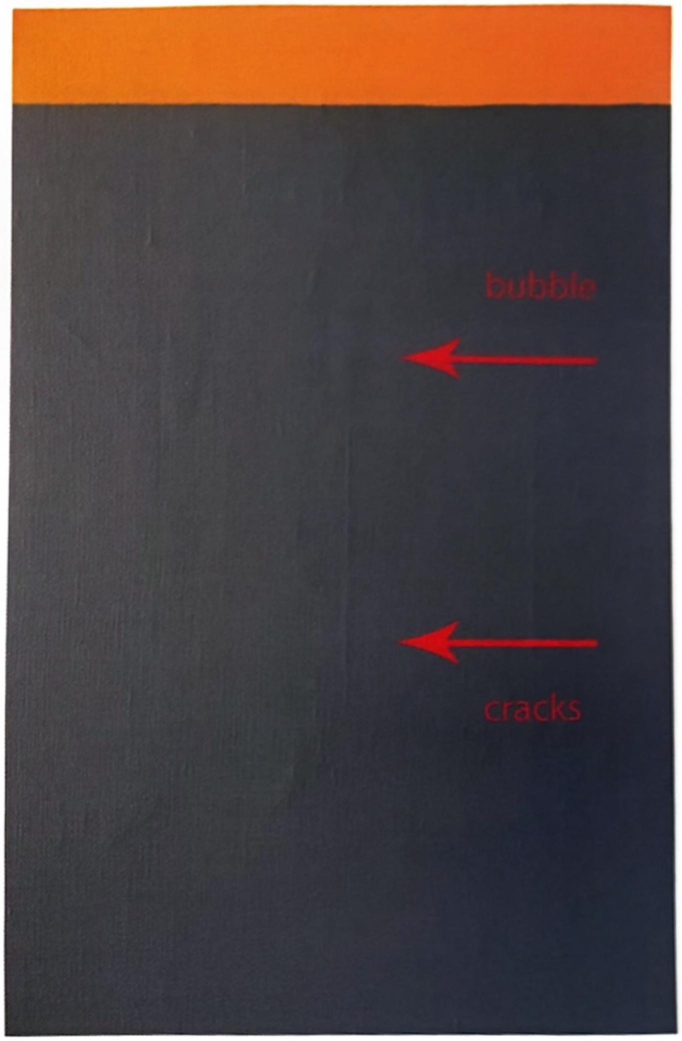

Figure 38.1 Detail of a 1959 Minimalist oil painting lined with Beva. Note the delamination of the cracks for which it was originally treated, as well as bubbles caused by local adhesive failure. Photographed in 2013. Image: Mary H. Gridley

The use of a very stiff lining material or interlayer, such as heavy Mylar, has proved successful in some cases, but in others such interventions only locked the partially flattened cracks in place. The same can be said for thickly flocked PVA adhesives, as noted above. Their stiffness overwhelmed the lining fabrics, and they cannot be reversed without a great deal of mechanical force or solvent (Rabin 1976). Local treatments with patches have resulted in unsightly bulges over time, caused by the shrinking of adhesives combined with realignment of forces between those canvas fibers that are held in place by adhesives and those that are not (fig. 38.3).

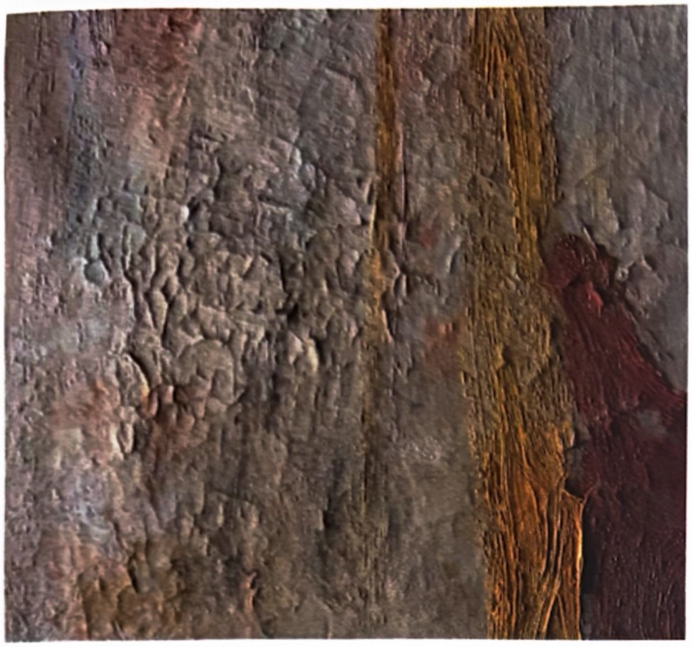

Figure 38.2 Detail of a 1956–58 oil painting lined with wax resin. The cupping has reappeared. Photographed in 2016. Image: Mary H. Gridley

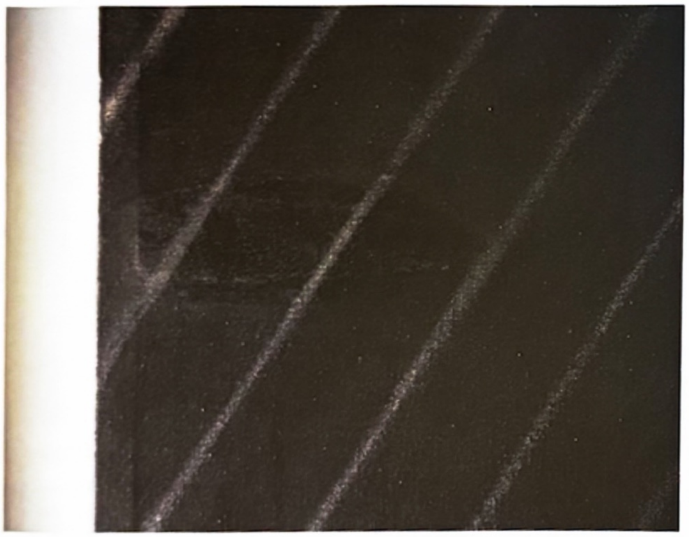

Figure 38.3 Detail of a 1959 oil painting showing the bulge caused by an old patch to mend a horizontal tear. Photographed in 2012. Image: Mary H. Gridley

For paintings meant to be displayed without frames or with only modest strip frames, the bulk added by any kind of lining fabric and adhesive can compromise the crispness of a painting's edges by forcing some of the unpainted tacking edge onto the face of the painting. Many of these treatments are difficult or impossible to reverse, and often lead to devaluation, both aesthetic and financial. Even past treatments sanctioned by the artist are subject to scrutiny. What was once acceptable, maybe even cutting edge, is now often viewed as undesirable in modern and contemporary paintings.

Local Treatment and Preventive Conservation

The most common structural damage we see in our studio is impact-related cracking of the paint film. This type of cracking often takes the form of concentric circles or feather-like shapes, resulting from accidental knocks to the face or the reverse. They also appear as straight lines directly on top of the edges of stretcher lips, rails, and crossbars, caused by repeated contact with the sub-support, or as smaller systems along the crossbars where people have distended the back of the canvas while grabbing the bars in transit.

While aesthetically disturbing, these impact damages do not always pose an actual threat to the overall stability of the painting. Successful flattening of such damage has always depended on softening or reforming both the paint and ground layers while simultaneously stiffening the canvas layer. Doing this successfully through localized treatment is possible, but the history and literature on treating cracks without resorting to lining is scant and the conclusions often discouraging. Moisture, solvent, heat, and pressure have been explored in various combinations (Gridley 2017). Experiments have been carried out in which the reverse of the canvas is treated in various ways to equilibrate the distortion caused on the face by local breaks in tension (Hough and Michalski 1999; Dimond and Young 2003; Hough and Michalski in this volume), but there are practical challenges, and local treatments are not always less time-consuming than global interventions.

Treating numerous similar damages one by one can be both labor intensive and expensive. However, there are collectors for whom an "untouched" or minimally treated artwork commands a premium, so there is value in underwriting the cost and time such treatments consume. This attitude has allowed our studio to develop expertise in carrying out such treatments. Treatment of impact cracks is often the first structural intervention in a modern or contemporary painting's life, and it is very important to acknowledge that better future treatments may be possible only if we tread lightly now.

As noted earlier, the current and widely adopted approach to structural repair of modern and contemporary paintings is one where a desire for local or minimal intervention meets a growing respect for authenticity. For example, there is perceived value in an unlined painting, with its original wooden auxiliary support and the verso of the canvas available for viewing. For eyes now accustomed to localized treatment of cracks or thread-by-thread tear mends, linings can appear heavy-handed. The occasional request to remove old linings without replacing them does not always occur because the lining has failed. More often, the lining itself is viewed as an undesirable condition of the painting. The many types of values embraced by stakeholders—unblemished surface, stable condition, age-appropriate damage, retention of hidden original or authentic components, unease with evidence of past conservation—are often contradictory, if not actually mutually exclusive, and present thorny ethical dilemmas when discussing treatment.

While minimal intervention and authenticity often complement each other in a treatment, that is not always the case. Removing a lining to reveal the original verso is not a minor treatment. Unstretching a painting to replace or modify an original subsupport that is inadequate or actively damaging the painting is not without risk and may end with an unsatisfactory compromise (fig. 38.4).

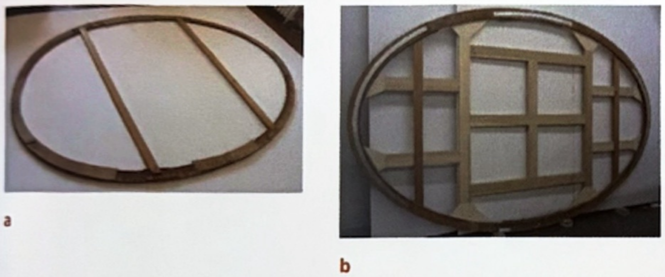

Figure 38.4 (a) Artist-made strainer from 1970 composed of wood, plywood, and particle board, 180.3 x 287 cm (71 x 113 in.). (b) The same strainer, modified in 2018. The effort to keep the original components and achieve adequate structural integrity resulted in a strange hybrid support. Images: Mary H. Gridley

An important strategy for mitigating against the return of old cracks or the creation of new ones involves preventive conservation. The installation of backing boards and handles prevents knocks from the reverse or edges being gripped during transport and installation. More complex interventions include stretcher bar linings or loose-linings for individual paintings. Where appropriate, framing and glazing are good protection, as are wrapping and crating to prevent contact with the face of the painting. Preventive conservation, while perhaps not understood by galleries or collectors to be a whole subspecialty of our profession, is something of which they are very aware. Proper storage, professional shipping, and environmental controls are not just institutional priorities; they have worked their way into the mindsets of commercial galleries, private collectors, and art handling and storage facilities.

MODERN MATERIALS

Successful local treatment relies to some extent on the material integrity of the painting itself. If the canvas still has adequate strength and the paint films remain relatively coherent and well adhered to the support, minimal intervention can both solve the current problem and leave the door open to future treatments. While some artists have incorporated unpredictable and problematic non-art materials into their works, generally the increased use of synthetic polymer-based materials and cotton supports in modern and contemporary paintings has advantages in problem-solving localized treatments.

Perhaps the most significant material difference between older and newer paintings is the widespread use of acrylic grounds and synthetic sizing. I would estimate that 90% or more of the post-1965 paintings I have examined, regardless of the type of support fabric or paint medium, are painted on acrylic grounds. The fast-drying, nontoxic qualities of acrylic grounds and sizing are very appealing to painters. In a nod to both this and to conservation research, one American manufacturer, Gamblin Colors, has even discontinued sales of rabbit-skin glue sizing and its proprietary traditional gesso (which also contained rabbit-skin glue). In doing so, Gamblin cited scientific research by the Smithsonian Conservation Lab that deemed these materials to perform poorly on canvas paintings over the long term due to the high reactivity of the glue and fabric to changes in RH. The more brittle paint layer(s) do not swell and contract as easily, and this incompatible elasticity can result in cracking or delamination of the paint (Gamblin n.d.).

In the past two decades, significant analysis and research has been done on acrylics. Much of it has centered on the various paint components and additives, as well as their aging properties, and what that means for cleaning,[2] but from a structural repair perspective, acrylic has some unique features. Its continued sensitivity to moisture, heat, and commonly used solvents such as alcohols and ketones makes it an ideal candidate for reforming (Zumbühl et al. 2007). When the acrylic is confined to the ground and size layer, with other media in the image layers, there are additional opportunities to manipulate its properties, allowing less interference with the paint and canvas layers.

Since World War II, when imported linen was hard to come by, cotton duck has been widely used in the United States, and to a lesser degree elsewhere. It became popular due to availability of large bolt sizes and comparatively low cost. It is unclear what the widespread use of cotton supports will bring us in terms of future structural problems, but in my experience they seem to suffer less embrittlement than linen during aging, even though the shorter and fluffier fibers are harder to work with individually, as required in a thread-by-thread tear mending. Linen, still widely used globally, retains its strength and resiliency for decades, allowing conservators to delay lining or other major structural interventions. Ongoing research into the materials and structure of aging contemporary primed canvases remains necessary to guide us in the future (see Carter et al. in this volume).

CONCLUSION

Structural treatment of modern and contemporary canvas paintings presents both technical and aesthetic challenges. In the private sector, treatments are judged not only by improved aesthetics or stability but sometimes also by how readily detectable a treatment may be to a future observer. While the various stakeholders—collectors, artists, and conservators—all wish for a work to be exhibitable, their definitions of that may not be identical, and furthermore are bound to change as the artworks and their components naturally age and new treatments evolve. The struggle to achieve a near-perfect surface while exercising restraint in intervention continues to drive innovations in treatment. The field has come a long way in the last seventy-five years: refined technical abilities, in-depth materials analysis, and a shared philosophical framework have allowed us to bring a more nuanced understanding to our work.

NOTES

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1. Daniel Goldreyer was in private practice, active from approximately 1950 to 1995. Orrin Riley was at the Guggenheim Museum and in private practice from about 1960 to 1986. Jean Volkmer was at the Museum of Modern Art ca. 1958 to 1983. Margaret Watherston was at the Whitney Museum of American Art and in private practice from around 1965 to 2005.
2. For a foundational overview of modern paints, see Learner 2004. For a brief summary of cleaning research, see Ormsby and Learner 2016.

Wax-Resin Extraction Traction on a Late Georges Braque Still Life

Desirae Dijkema, Assistant Paintings Conservator, The Menil Collection, Houston, Texas
Bradford Epley, Chief Conservator, The Menil Collection, Houston, Texas

In 2018, the Conservation Department of the Menil Collection performed a novel wax-resin extraction treatment utilizing Evolon CR on Pitcher, Candlestick, and Black Fish *(1943) by Georges Braque. The treatment was preceded by extensive wax-resin extraction trials; multiple methods of extraction were tested, focusing on the variable contributions of heat, suction, solvent selection, and the capillary action of an Evolon CR substrate. Based upon optimized parameters determined in the preliminary trials, the wax-resin extraction treatment on the painting was performed on a suction table, utilizing xylenes-saturated Evolon CR against the back of the canvas, ShellSol OMS–saturated Evolon CR against the face, and two cycles of suction and heat. Visually, the canvas regained weave distinction and a variety of surface that is inherent to the way that paint conforms to fabric. Spectrophotometry readings taken before and after wax extraction show a perceivable lightening of the ground. After treatment, the weight of the canvas had decreased by 14%.*

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INTRODUCTION

"Why subject it to this rack-like torture? . . . Restorers are amazing. They have transformed my guitar into a tambourine." So said Georges Braque to John Richardson after viewing one of his still lifes that had been wax-resin lined. He completed the sentiment with a tap of his brush on the painting's taut surface (Richardson 2004, 533).

In 2016, the Conservation Department at the Menil Collection began a long-anticipated cleaning of Georges Braque's 1943 painting *Pitcher, Candlestick, and Black Fish* (*Vase et poisson noir*). The painting had been treated in 1961 by Caroline Keck, receiving a "superficial cleaning," wax-resin lining, and a poly butyl methacrylate varnish.[1] The motivation for lining was largely preventative. In a letter in the painting's file, Keck explains that "the result of the rolling and its mishandling has caused cracks to develop, some easily seen with the eye in the yellow area, others developing definitely in the structure but visible under magnification only at this stage . . . this is an important moment to treat the painting, to prevent any serious damage and even loss of surface as these cracks go further."[2] The painting was likely rolled twice in 1940, when Braque traveled to the south of France and then back to Paris at the beginning of World War II (Danchev 2006).

That Braque sought variation in his final surfaces is effectively demonstrated by Favero, Mysak, and Khandekar in their technical study of twenty-one of his paintings from 1928 to 1944. Braque achieved a variety of textural effects by mixing sand, fine gravel, and quartz into his grounds or using combs and sculptors' tools to scrape through wet paint (Favero, Mysak, and Khandekar 2013). He created more delicate variations of surface by mixing varnish or beeswax into the paint or by selectively varnishing certain passages. Richardson describes Braque's practice of applying a varnish to certain passages, sometimes according to a viewer's expectations of an object's reflectance (as in his paintings of the 1920s and 1930s, where shiny objects such as a glass vase received a glossy finish while matte objects such as a lemon received nothing), or sometimes in deliberately playful ways that go against a viewer's expectations by rendering inherently shiny objects matte (Richardson 2004, 533).

In *Pitcher*, the cleaning revealed that Braque manipulated the final surface sheen with two black paints—one that is velvety matte and one that is glossy—to establish subtle contrasts across the surface.[3] For instance, a fish featured in the foreground is almost entirely painted in matte black paint except for two small reveals around its eye and gills where Braque left underlying glossy paint in reserve, creating a shiny iris and gleaming gill line (fig. 39.1).

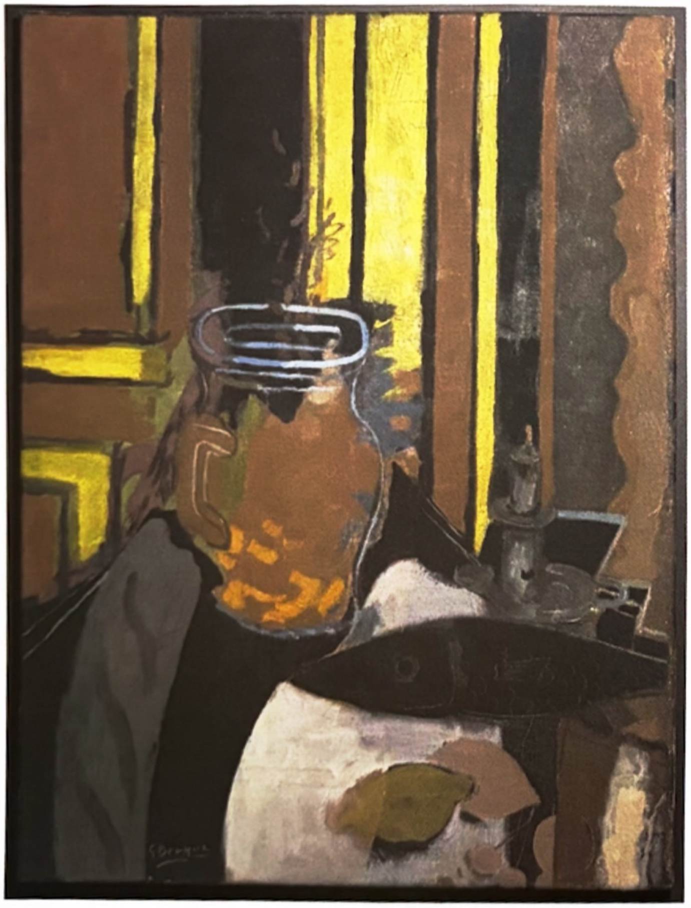

Figure 39.1 Georges Braque (French, 1882–1963), *Pitcher, Candlestick, and Black Fish* (*Vase et poisson noir*), 1943. Oil on canvas, 64.8 × 49.5 cm (25 1/2 × 19 1/2 in.). During treatment (after cleaning and lining removal, before wax-resin extraction), under specular illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

In addition to creating variable gloss and matteness, Braque manipulated the texture of *Pitcher*'s surface. Fine sgraffito marks outline the lemons, and medium to wide gouges create detail in the background, indicating that Braque used a variety of tools to establish a variable surface with tactile characteristics. In certain passages, grooves unite with precise paint application, merging the textural and the visual: two gouges extend upward from a cherry in the foreground, revealing dark underlying paint and beginning its stem; after approximately 1 centimeter, a fine stroke of brown paint fills them in and completes the stem's length.

At some unknown date prior to Keck's 1961 treatment, the painting had also received a bleached shellac coating.[4] Though it is unclear who applied the shellac coating, two reasons make it highly unlikely to have been Braque: his dislike of overall varnishes for their unifying effect on sheen, and the areas of retouching underneath the shellac layer that were discovered during the cleaning. These had been incorrectly applied to grooves in the paint that were misinterpreted as abrasions; there are multiple examples of similar, nonretouched grooves throughout the composition. During the lining process, the shellac had softened and deformed from exposure to heat and pressure, resulting in a tangled network of ridges and valleys that imparted an artificial texture across the surface. Visible under magnification and to the naked eye, the compromised shellac scattered light and hindered legibility of subtle brushstrokes and sgraffiti.

Given Braque's practices regarding his differentiated paint surfaces, the rationale for the 2016 cleaning was twofold: to reduce the compromised shellac and to restore the surface's original, varied sheen and texture by removing the varnish layers and their unifying gloss. The decision to pursue a lining reversal and wax-resin extraction was motivated in part by the possibility of enhancing reflective and textural gains revealed by the cleaning, as well as by the artist's aforementioned dislike of what he perceived as an artificial planarity and stiffness imposed by linings.

TREATMENT TRIALS

The wax-resin extraction on the painting was preceded by forty-eight test trials performed on strips of the lining canvas, which was removed from the painting mechanically by peeling it back at a low angle. Examination of the canvas fibers after removal of the lining revealed that they were in good condition and had not been shaved prior to lining. Of the trials, the first twenty-eight were more exploratory in nature, while the final twenty were more controlled, as the most important treatment parameters emerged. The lining canvas strips were subjected to different conditions exploring multiple variables, including solvent location in relation to the bulk of the wax-resin mixture (whether the solvent was introduced from the back or from both front and back), the type of solvent, the solvent delivery system (brush-applied, gelled, or by fabric), the wicking layers (number of layers, type of material used, and frequency of change-out during treatment), the temperature, and the use of suction. Initially, gels were used as a solvent delivery system, after the methods published by Bettina Landgrebe and Gunnar Heydenreich (Landgrebe 1988; Heydenreich 1994). However, relatively early on it became clear that Evolon CR could deliver solvent as effectively as a gel, while minimizing preparation and simultaneously acting as a means for absorption.

A general setup of the trials from the Willard suction table surface upward was as follows: heat and/or suction provided by a vacuum hot table, one to three wicking layers (Evolon CR, paper towels, or linen), an "acting" solvent layer (sheet of Evolon CR or gel containing a solvent with a high chemical affinity for the wax resin), the lining canvas strip faceup,[5] and in some trials a low-polarity "superficial" solvent applied by brush or Evolon CR to the face. Evolon CR is a nonwoven textile composed of polyester and polyamide microfilaments that can absorb up to four times its weight in water and slightly more than that in hydrocarbon solvents.[6] The acting solvent layer is meant to promote dissolution of the wax resin, while the superficial solvent encourages movement of deeply impregnated wax resin out of the lining canvas and into the wicking layers below.

Exploring a few trials in detail illustrates some key takeaways that ultimately informed the treatment parameters on the painting. The time-consuming nature of the trials made it difficult to do extensive investigations of all variables. Trials included here offer empirical findings and observations. Moving forward, performing a greater number of trials per single variable will be necessary in order to form conclusions that are statistically relevant.

Efficacy of wax-resin removal was evaluated based on the appearance and feel of the lining canvas strips and their percentage of weight loss after treatment. In order to establish the maximum amount of wax resin that could be extracted, small coupons of lining canvas were individually weighed, and then each was immersed in one of the range of solvents being considered for use (xylenes, ShellSol Odorless Mineral Spirits [OMS], hexamethyldisiloxane, and octamethylcyclotetrasiloxane) for approximately forty-eight hours, after which it was removed from the solvent, allowed to dry, and reweighed. This demonstrated that the maximum amount of wax resin that could be extracted was around 30% of the weight of the coupon. The most successful solvents, xylenes and ShellSol OMS, resulted in 31% and 32%, respectively.

Trials that involved application of solvent to the face resulted in the supplest canvas feel and the best final appearance—clarity of weave, saturation, evenness of wax-resin removal—with comparable results regarding weight-loss percentage. In a set of eight trials, four involving superficial solvents and four without, all of those involving superficial solvents resulted in the supplest canvas feel and most improved clarity of canvas weave. While it was clear that the application of solvent to the face would not necessarily result in a higher percentage of weight loss (taken as a measure of efficacy of wax-resin removal), the visual and tactile characteristics were deemed more improved in the lining canvases that had received superficial solvent than in those that had not.

Using xylenes as the acting solvent consistently dissolved more wax-resin mixture than did ShellSol OMS. Trials with xylenes in the acting solvent layer resulted in good clarity of weave with no visible wax-resin residue, a supple canvas feel, and higher weight-loss percentages. Trials with ShellSol OMS in the acting solvent layer resulted in visible wax-resin residues, lower weight-loss percentages, and a blanched final appearance, likely resulting from incomplete dissolution of residual wax resin.

Halfway through the trials, it became clear that the downward draw of the wax-resin mixture into the Evolon CR via capillary pressure was significantly stronger than any contribution from the downward draw of air by the suction table. In trials with and without suction, both trials resulted in good clarity of canvas weave, no visible wax-resin residue, a supple canvas feel, and comparable losses in weight. However, it was important to use the suction table anyway, for two reasons: as a means of ensuring close conformity between the lining canvas strip and the Evolon CR, and as a means to evacuate solvents and avoid a solvent-package effect. In trials without suction, droplets of solvent were visible pooling on the underside of the Dartek covering the stack, which we deemed a nonviable method for the eventual treatment of the painting.

Consistently more wax resin was extracted when the trials involved heat. The strong capillary effect of the Evolon CR raised the possibility that extraction utilizing the solvent might be possible at room temperature. Trials performed at approximately room temperature resulted in a slightly improved clarity of canvas weave on the back of the strip, but an increased obfuscation of weave and darkening on the front. The canvas remained stiff after treatment and underwent minimal weight loss.

Using a larger volume of acting solvent results in a higher percentage of weight loss in the lining canvas strip. In a set of four trials—two involving an acting solvent layer of twice the weight of the Evolon CR and two involving three times the weight of the Evolon CR—trials involving the larger volume of solvent resulted in the highest percentage of weight loss.

When it came time to design the treatment methodology for the painting, several parameters had become clear from the trials. A low-polarity superficial solvent, xylenes as the acting solvent, suction for solvent evaporation and conformity, and heat would result in the highest percentage of weight loss and the best final feel and appearance of the canvas. In spite of the success of trials involving higher volumes of solvent, we decided to load the Evolon CR with twice its weight in solvent (rather than three times), because of the relatively finer weave of the painting's canvas.[7] Other parameters were less certain, such as whether to change out the wicking layer once or twice, and whether one or two rounds of extraction should be performed. Ultimately, we decided to change out the wicking layer once in order to minimize handling and to determine whether a second round was necessary after seeing the results of the first round.

TREATMENT

Broadly speaking, the treatment involved applying Evolon CR that had been saturated with ShellSol OMS to the face and Evolon CR that had been saturated with xylenes to the back while placing the entire stack under heat and suction. As in the trials, the volume of solvent in the Evolon CR was determined by weight. In order to load the Evolon CR with solvent, a sheet of the material was weighed, rolled, and folded and placed in a clean, empty metal paint container. Double its weight in solvent was added, and the container was sealed and left overnight. The painting was weighed before and after treatment by placing it on a rigid board and subtracting the weight of the board alone from the weight of the two together. Spectrophotometric measurements were taken before and after treatment.

The treatment occurred in two rounds, each comprising three stages. For all rounds, the Evolon CR was applied as single sheets cut larger than the size of the painting.

In the first stage:

- A cross section of the material stack from the Willard table upward is as follows: Hollytex to prevent adhesion to the lining table; a dry sheet of Evolon CR as a wicking layer; Evolon CR saturated with twice its weight in xylenes (the equivalent of 100 mL); the painting faceup; and Dartek.
- The table temperature was set to cycle between 39°C and 51°C, though the temperature at the painting's surface consistently registered 2°C–3°C lower when checked with an infrared thermometer.
- With suction set to 2 mbar, the painting was left in this stack configuration for 15 minutes.

During the second stage:

- The Dartek was temporarily removed, Evolon CR with twice its weight in ShellSol OMS (the equivalent of 120 mL), was placed over the front, and the Dartek was replaced.
- The table temperature's cycle remained the same (39°C–51°C), and the painting's surface continued to measure 2°C–3°C lower.
- The suction was increased to 7 mbar, and then the painting was left for twenty minutes.
- After twenty minutes, the wicking Evolon CR was replaced with a new, dry sheet, the Dartek was put back in place, and the stack was left for another twenty minutes.

During the last stage:

- The Dartek and Evolon CR on the face were removed.
- The heat was turned off, but the suction was left at 7 mbar.
- The painting was left to cool for thirty to fifty minutes while light suction encouraged solvent evaporation

Wax-resin residues were clearly visible on the back of the canvas after the first round, so all three stages were repeated for a second round.

TREATMENT RESULTS AND DISCUSSION

When considering the treatment results, there are a variety of aspects to consider, including the aesthetics of the pictorial layer, the planarity of the support, the appearance of the back of the canvas, the percentage of weight loss,

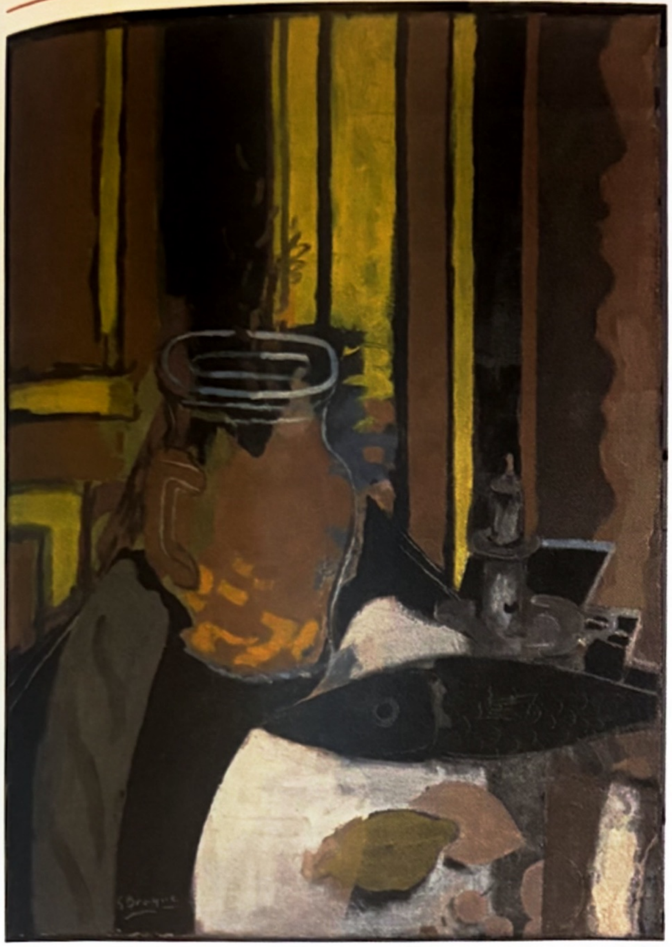

Figure 39.2 *Pitcher, Candlestick, and Black Fish* after treatment, under specular illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

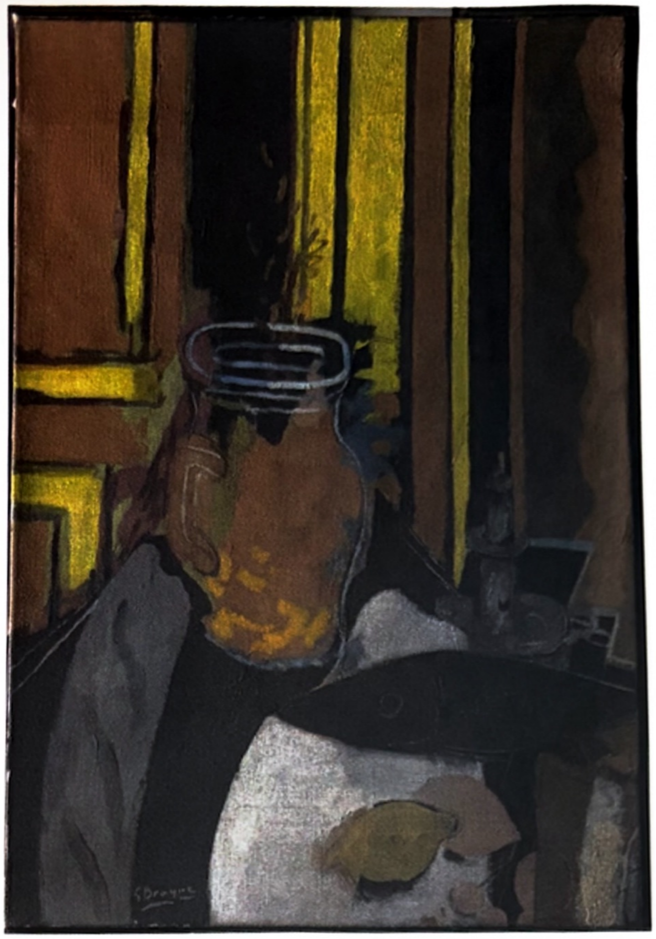

Figure 39.3 *Pitcher, Candlestick, and Black Fish* after treatment, under raking illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

and color change. The wax-resin extraction resulted in relatively subtle changes to the pictorial layer. The colors in the face of the painting were not significantly altered, but there was a clearly perceptible lightening of the ground visible on the tacking margins. The painting does not have areas of exposed ground within the design, as do many of Braque's pictures, so the impact of this brightening upon the overall color harmony of the composition is less noticeable than it would be if the ground was a defining element. There was no perceivable change to the painting's varying sheens of matte and glossy black paints (fig. 39.2; compare to fig. 39.1).

The planarity of the canvas is now visibly more congruent with the age of the paint layer, as it no longer has the rigid tautness it did before. Six horizontal cracks spanning the painting's width are more prominent, resulting in subtle planar distortions that are visible in the final stretching (fig. 39.3). These cracks likely relate to when it was rolled during Braque's evacuation from Paris at the outset of World War II; their return makes visible an aspect of the painting's history that was previously masked by the lining's flatness. In addition to evidencing history, this return of dimensionality restores a relationship between paint and support that is more in keeping with Braque's governing thoughts about the artistic process. Favero et al. have eloquently summarized these using an example described by the artist: "For Braque, color was inextricably bound to material and texture: 'Dip two white cloths, but of different material, into the same dye; their color will be different'" (Favero, Mysak, and Khandekar 2013, 99).[8] Restoring the pliancy of the linen that had formerly been restricted by the wax resin creates an interaction between color and support that was previously absent.

In addition to an improved clarity of weave, a number of previously invisible marks became apparent on the back of the canvas after the saturating effect of the wax resin was removed (figs. 39.4, 39.5). There are areas where the ground has seeped through the canvas (fig. 39.6), and several dark marks, some of which follow contours of an underlying figural composition.

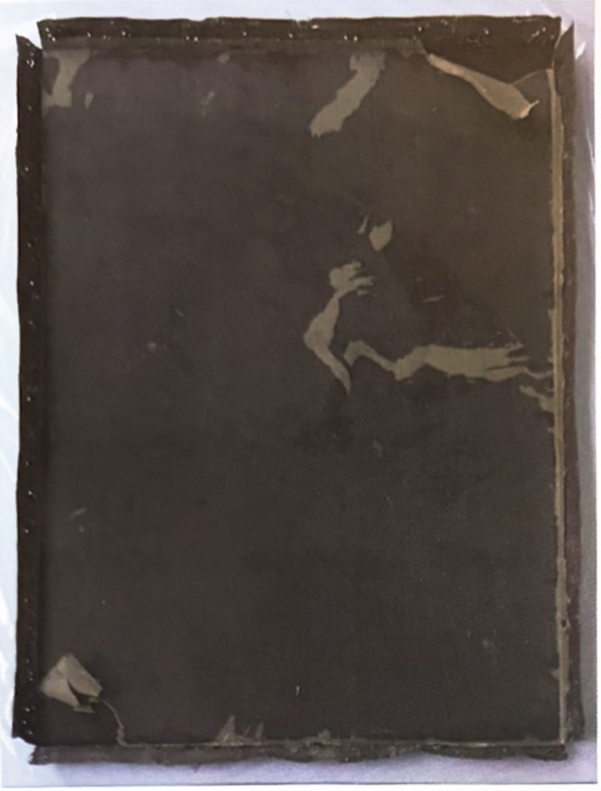

Figure 39.4 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting before wax extraction with interleaf intact, under available illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Desirae Dijkema

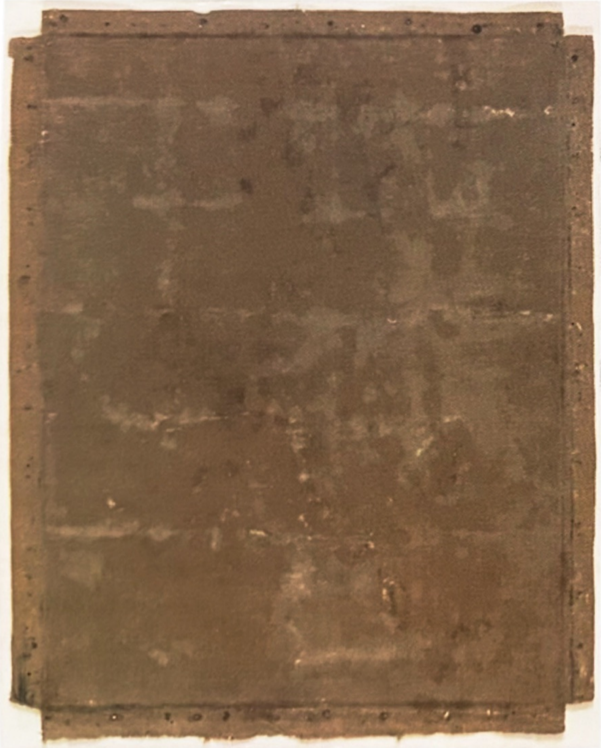

Figure 39.5 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting after wax extraction, under normal illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

Figure 39.6 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting after wax extraction, detail. Notice the ground seeping through the canvas in the lower center. Light areas of blanched wax residue that correspond with cracks on the front are seen in the cross-shape form to the right of center and the elliptical shape near the center of the left edge. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

Several areas of lighter canvas appeared on the back, including six horizontal lines corresponding with cracks on the front, in addition to a few larger forms, coinciding with areas of thin paint application. It seems likely that these and other intermittent light areas are areas of blanched wax or wax resin left in the canvas interstices. Some of these light areas have fine white deposits; Fourier transform infrared (FTIR) analysis of a sample from one deposit closely matches the reference spectra for wax.[9] Current analysis is inconclusive regarding the presence of a resin such as dammar, Ketone Resin N, or Zonarez B-85, which were common components in the Kecks' wax-resin mixtures.[10] Analysis of the white deposits with gas-chromatography mass-spectrometry is forthcoming. UV photos taken of the back of the canvas after extraction show a faint fluorescence in these areas, suggesting the presence of wax or wax-resin residues (fig. 39.7). The blanching may be related to the higher evaporation rate of solvents at an air interface, such as a comparatively open pathway of a crack versus a solid paint film (Hansen 1970).

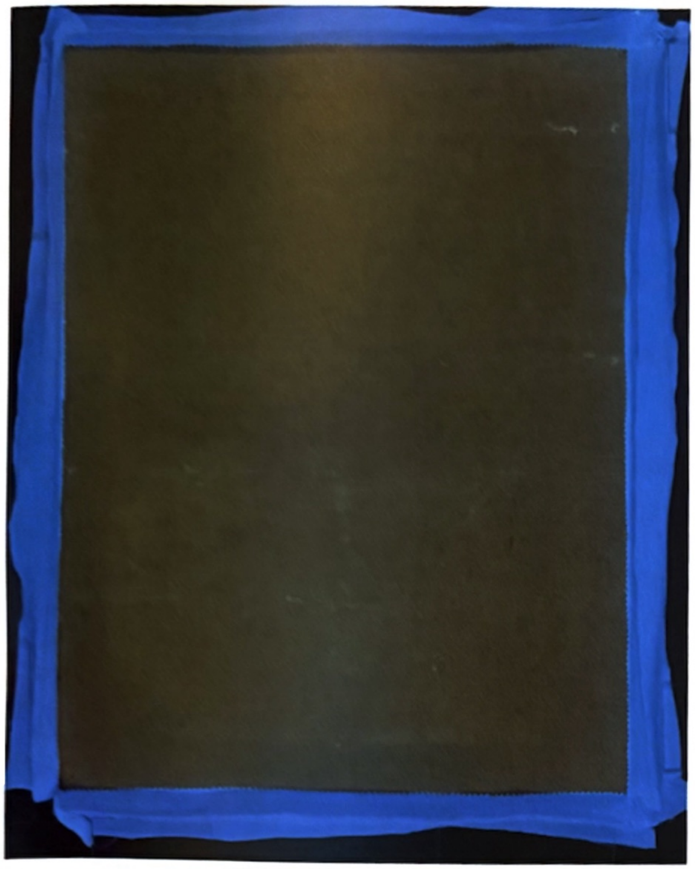

Figure 39.7 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting after wax extraction and edge-lining, UV-induced visible fluorescence. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

UV photos were taken of all eight Evolon CR sheets used during treatment as a way of visualizing the wax resin's location after extraction. The sheets on the face showed almost no wax-resin absorption, save for residues on the tacking margins and turnover edges. The acting solvent layers show an even distribution of wax resin, as do the dry wicking layers placed underneath for the first half of the treatment rounds. The wicking layer that was placed underneath the acting solvent layer for the second half of the treatment rounds shows an uneven distribution and minimal absorption of wax resin. Comparison with the front of the painting indicates that the distribution of wax resin in the wicking layer corresponds to cracks and thin paint layers. As mentioned, the pattern of UV-fluorescent and blanched material suggests that these areas retained wax throughout each treatment round. It seems likely the wax resin was not removed entirely because a higher solvent evaporation rate inhibited sustained dissolution.

The weight of the canvas decreased by 14%, a percentage significantly lower than the weight changes that were achieved during the most successful trials, which were consistently over 30%.[11] The percentage difference between the trials and the painting does not necessarily mean less wax resin was removed, however, because—when compared to the lining canvas strips—the wax resin contributed less to the weight of the painting due to the paint and ground layers.

Spectrophotometry measurements were taken from fifteen locations in total: three from the ground on the tacking margins and twelve from areas within the face of the painting. The measurements of the ground on the tacking margins confirmed quantitatively what is apparent visually: the color of the ground became lighter and warmer.[12] The ΔE_{76} of an average of three measurements taken from the ground is 4.12 ± 0.41, the L* increased by 3.71 ± 0.37 toward white, the a* increased by 0.537 ± 0.12 toward red, and the b* increased by 1.71 ± 0.20 toward yellow. It is likely that the reduction in wax resin increased scattering, resulting in a brighter color (Rees Jones 1991).

Following the wax-resin extraction, the tacking margins received an edge-lining with linen and Beva 371 film. During restretching, some consolidation was necessary along the turnover edges, and it was possible to use sturgeon glue, indicating the possibility of treatment with aqueous methods. The painting will receive a rigid backing board and will be reframed and glazed.

MOVING FORWARD

There are several avenues that deserve further research. The time at which the wicking layer is changed out should be reconsidered. The wicking layer that was in place for the *first* half of each treatment round appears to have absorbed an amount of wax resin that is comparable to the xylenes-saturated sheet. The wicking layer that was in place for the *second* half of each round appears to have absorbed the least amount of wax resin. Perhaps the xylenes-saturated sheet above the wicking layer became too saturated with wax resin by this point in the treatment to allow further absorption below it. Or perhaps there was not enough solvent in the system to encourage movement of the wax resin into the Evolon CR. Understanding the timeline of wax-resin absorption better could help to bring about more efficient future treatments.

Exactly what was extracted needs to be identified. Does what was removed correspond with the components of the wax-resin mixture? Have certain materials been preferentially removed? Are there differences between the composition of the material present on the Evolon CR on the back and that on the front? Analysis is pending on extractions from the Evolon CR sheets used during treatment.

It is worth exploring whether there are alternative hydrocarbon solvents that would be equally effective. As evidenced by the solvent-immersion test, ShellSol OMS actually extracted a similar amount of wax resin by weight to xylenes (32% compared to 31%). Clearly, it had an affinity for the wax-resin mixture, but it takes longer to work. Solvents with similar properties should be explored, perhaps ShellSol D38.

Weight loss per surface area should be measured instead of weight change percentages, as Gunnar Heydenreich did in his 1994 wax-resin extraction treatment (Heydenreich 1994, 25). This will more easily allow for comparison of wax-resin loss across samples of varying weights and sizes. The impact of a higher solvent volume on the amount of wax resin extracted should be explored with more trials. Perhaps using a higher volume with a shorter treatment duration could optimize the amount of wax resin extracted while minimizing solvent and heat exposure.

We need to better understand what is causing the blanching around cracks and areas of thin paint. Is it related to incomplete wax-resin removal, a higher rate of solvent evaporation, or a combination?

CONCLUSION

Wax-resin linings have a mixed legacy—they partially address physics at the expense of certain aesthetics. Qualities like saturation and color harmony are sacrificed for a planarity free from distortions that can impair legibility. Though wax-resin impregnation has been shown to improve tensile properties (Hedley 1975) and increase protection against changes in humidity for short exposure times (Young and Ackroyd 2001), it has also been shown to increase contraction forces resulting from long exposures to high humidity (Andersen et al. 2014).

Its impact on color change is similarly contradictory. Wax-resin linings affect color saturation to varying degrees, dependent upon the presence of sizing, pigment type, medium type, layer thickness, and hiding power (Nieder, Hendricks, and Burnstock 2011, 98; Froment 2019, 439). Bomford and Staniforth have demonstrated that wax-resin impregnation has a significant impact on the color of canvas of varying weights as well as grounds of differing compositions, particularly those that are underbound, but whether such a change is visible in the painting is dependent on the degree to which the canvas or ground plays a visible role in the composition (Bomford and Staniforth 1981). Though recent studies have indicated that certain artists chose to have their paintings lined very early in a painting's life or even during the painting process (Hackney 2004b), it is clear from Richardson's writings that Braque preferred a surface in which the variable qualities of stretched canvas are visible.

A treatment such as this one is not undertaken lightly. In terms of solvent amounts and their potential effects on paint films, the treatment is not dissimilar to the process of cleaning. Above all, the words of the artist offer direction. Without its lining, *Pitcher, Candlestick, and Black Fish* presents a planarity that is more congruent with its age and honors its history. Furthermore, reduction of the wax-resin adhesive allows physical response to environmental fluctuations. Perhaps most importantly, it restores the relationship of the canvas's materiality and paint layers to one more in keeping with Braque's artistic practice. When considering Braque's statements about the interconnectedness of those two elements at the start of treatment, the question became: Why continue to subject it to this rack-like torture?

ACKNOWLEDGMENTS

The authors thank Corina E. Rogge for her technical analysis and guidance, Adam Neese for the extensive technical imaging of the painting, Anne Schmid for her exhaustive literature review of wax-resin reversals and extractions, Christina McLean for her assistance during treatment, Katrina Rush for sharing her treatment knowledge of other works by Braque, Rebecca Rabinow for her curatorial insight regarding Braque's working practice and provenance research, the Yale University Art Gallery for hosting the Conserving Canvas symposium and coordinating the publication of these postprints, and the Getty Foundation for promoting the exchange of knowledge through funding the Conserving Canvas project.

APPENDIX A: MATERIALS AND SUPPLIERS

DMF-0.65, hexamethyldisiloxane, a linear silicone solvent (not to be confused with dimethylformamide) that is completely volatile. Average viscosity 0.65 cst at 25°C. Shepard Bros., Inc. http://www.shepardbros.com

CSF-4 octamethylcyclotetrasiloxane, cyclic silicone solvent that is completely volatile at flash point: 59°C, Shepard Bros., Inc. http://www.shepardbros.com

Dartek F-101, cast nylon film (nylon 6,6). Distributor: TALAS. http://www.talasonline.com

Digital Bench Toploading Balance (for lining canvas strips): APX-153, Apex Series Balances, Denver Instrument, discontinued

Digital bench scale (for painting): CPWplus 35, Adam Equipment. https://www.globalindustrial.com/p/adam-bench-weighing-scale-75lb

Evolon CR, nonwoven fabric composed of polyester and nylon microfilaments, Deffner and Johann. https://deffner-johann.de/en/evolonr-cr-on-roll-102-cm-x-10-m.html

Hollytex, made from acid-free, fine, nonwoven, spun-onded 100% polyester. Distributor: TALAS. http://www lasonline.com

frared thermometer: Etekcity Lasergrip 774 Noncontact Digital Laser / Temperature Gun.

ShellSol Odorless Mineral Spirits, distributed by Conservation Support Systems, Santa Barbara. https://conservationsupportsystems.com/main

Sigma Aldrich Xylenes, ≥98.5% xylenes, ethylbenzene basis. https://www.sigmaaldrich.com/US/en/product/sigald/247642

Spectrophotometer: Konica Minolta CM 700d, 8 mm aperture, SCI (specular component included) / SCE (specular component excluded). https://sensing.konicaminolta.us/us/products/cm-700d-spectrophotometer/

APPENDIX B: TRIAL PROCEDURE

All trials involved the following procedure with adjustments for specific variables:

The material stacks were covered with Dartek and cycled between 50°C and 63°C for 70 minutes at two to seven mbar suction.

- Halfway through, the wicking layer was replaced with a new, dry sheet of Evolon CR.
- The entire process was repeated for a second round.
- The weight of the lining canvas strip was measured before and after rounds 1 and 2, and percentage weight loss was calculated by dividing the difference of a lining canvas strip's weight from before round 1 and after round 2 by the initial weight of the lining canvas strip and then multiplying by 100. (Lining canvas strips were allowed to desaturate through evaporation for at least two days before weight measurements after round 2.)
- Evolon CR was loaded with solvent by weight: first the weight of the Evolon CR sheet was measured, then multiplied by two or three to determine the solvent weight. Solvent was added dropwise to the Evolon CR and sealed in a glass jar for two to twenty-four hours before the beginning of a trial.

NOTES

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1. It is assumed that "superficial cleaning" refers to dirt removal. Keck's treatment report says the painting was varnished but does not say with what. At the time they were treating *Pitcher*, the Kecks were also treating a Picasso from the de Menils, which *is* documented as receiving a poly butyl methacrylate lining in the same treatment report as Braque's *Pitcher* (Caroline Keck, letter in the conservation file, March 13, 1961). Sample T 703 s14 taken from a scraping in the varnish atop a yellow band in the background near the top center exhibited a spectrum that, through spectral subtraction, indicated that a butyl methacrylate–containing species could be present. Attenuated total reflectance (ATR) Fourier transform infrared (FTIR) spectra were collected by C. E. Rogge using a Lumos FTIR microscope equipped with a motorized germanium ATR crystal with a 100 µm tip (Bruker). The spectra are an average of 64 scans at $4\ c^{-1}$ spectral resolution, and an ATR correction was automatically applied by the Opus 7.0 instrument control and data collection software.
2. Caroline Keck, letter to Mrs. de Menil in the conservation file, February 9, 1961.
3. The painting was surface cleaned with saliva, the poly butyl methacrylate coating was removed with ShellSol A100 and cotton swabs, and the bleached shellac coating was removed with a sequential application of isopropanol and 2,2,4 trimethyl pentane (iso-octane) applied with cotton swabs or a brush while working underneath the microscope.
4. FTIR data taken by C. E. Rogge, using the same instrumental parameters as described in note 1 above. Photographs of the varnished painting taken under UV illumination showed a coating with a blue-green fluorescence, rather than the characteristic orange fluorescence typically associated with shellac. Chemical bleaching destroys the compounds responsible for the orange fluorescence. See Sutherland 2010.
5. The face was defined as the side that had the least amount of wax resin.
6. Evolon CR belongs to a line of fabrics made by Freudenberg that have a wide variety of uses, including anti-mite bedding, cleaning cloths, sound absorption, and sun protection. Evolon CR was developed by Deffner & Johann, a conservation materials and tools supplier in Germany, in discussion with the manufacturer specifically for use in conservation. It is PVC-free and produced without solvents or binders. See "Evolon CR," Deffner & Johann, accessed June 26, 2010, https://deffner-johann.de/en/evolonr-cr-on-roll-102-cm-x-10-m.html. Freudenberg Performance Materials, "Key Benefits of Evolon Technology," https://evolon.freudenberg-pm.com/evolon_technology/key-benefits, accessed April 12, 2022.
7. Other variables considered include the introduction of the superficial solvent as free solvent brushed over the surface or introduced by means of saturated Evolon CR; both produced similarly successful results. In practice, the saturated Evolon sheets proved a more reliable way of delivering a known amount of solvent uniformly across the surface and eliminating the variable pressure and delivery volumes associated with brush application. It should be noted, however, that the use of Evolon CR prevents observation of the paint surface during treatment.

[8] Favero et al. translated Braque as quoted in an interview with Dora Vallier, "Braque: La Peinture et nous: Propos de l'artiste recueillis par Dora Vallier," *Cahiers d'art*, no. 1 (1954): 16–22.

[9] FTIR data were collected by C. E. Rogge on June 23, 2020, with the same instrumental parameters given in note 1 above.

[10] Corina Rogge, FTIR spectroscopy results, June 23, 2020: "The background absorbance in the 1100-900 c^{-1} range is higher in this portion of the sample suggesting additional materials are present, but the low amounts, weak signal and lack of characteristic peaks preclude identification."

[11] Percentage of weight loss was calculated by dividing the difference of the painting's weight before and after treatment by its weight before treatment and multiplying by 100.

[12] Only the results from the measurements on the tacking margins are included here, as three measurements were taken, which permits calculation of standard deviation. The difference perceptible to the human eye has been a subject of debate in the literature since the 1980s. Some authors suggest that one CIELAB unit (1ΔE*) corresponds to the smallest difference that is perceivable to the naked eye, while other authors suggest it is between one and two units, and others above two. For purposes of comparison with other research, a ΔE* of 1 was defined as the perceptible limit in this paper. See Froment 2019, 140.

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Local Treatments of Cupped Cracks in Contemporary Paintings and Their Appearance after Twenty-One Years

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Single cracks in contemporary paintings on canvas can be disfiguring due to cupping. In 1999, the authors published a study of fourteen different methods for local treatment of such cracks, applied to slack paintings (Hough and Michalski 1999). Model paintings were created to simulate contemporary paintings of oil paint on acrylic ground on cotton duck fabric. Nine cracks, each 15 cm (6 in.) long, were created in each of nine paintings. Profiles of the treated cracks were monitored over a period ranging from five minutes to seventy days. Only three of the treatments gave good results at seventy days. The results were consistent with the known viscoelastic properties of the materials used. A year later, three paintings were keyed out in order to study the taut condition, where cupping is driven by stress alignment rather than curl, and to study the tendency of the repairs to surface. In 2018–19, the samples were reexamined. Surfacing had become pronounced in many but not all of the samples that had been keyed out: one treatment still looked good. In this paper, the mechanisms causing cupping and surfacing are modeled and the predictions compared to the experimental results.

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INTRODUCTION

Single cracks or localized cracks in contemporary paintings on canvas can be disfiguring due to cupping. A local treatment, if successful, has the advantage of avoiding risks that a whole painting treatment presents to the remainder of the painting. Although cupping may be removed temporarily by moisture, solvent vapors, and/or heat, maintaining flatness may require reinforcements, which in turn may surface.[1] In 1999, we published a study of fourteen different methods for local treatments of such cracks in slack paintings (Hough and Michalski 1999). Here, we will discuss the appearance of these treatments in paintings twenty-one years later, with and without keying out (i.e., with both taut and slack conditions).

MECHANICAL MODELING

Curl and Stress Alignment

During curing, paint layers (which are "fatter" layers) attempt to shrink more than ground layers (which are "lean"). If a crack forms and if the painting is slack, this differential shrinkage curls the painting at the crack, as shown in figure 40.1a.

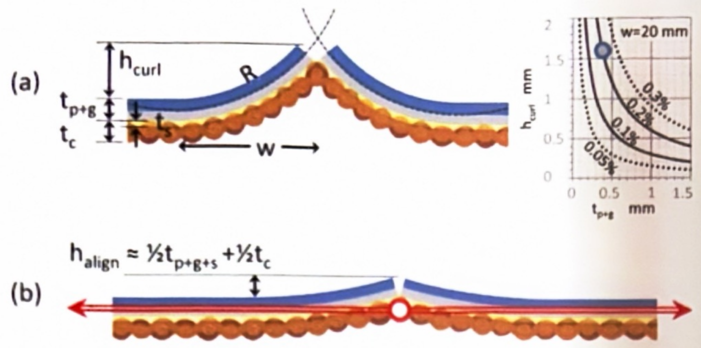

Figure 40.1 (a) Curl, caused by greater shrinkage in the paint (blue) than in the ground (gray). Inset graph for curl height for various differential shrinkages and a width of 20 mm, assuming no restraint by the size of the canvas (slack). (b) Stress alignment (red line) in a taut painting. The canvas hinge (red circle in center) aligns with the stress that is centered in the intact size, ground and paint adjacent. (R) radius, (h) height, (t) thickness, (w) width. Subscripts: (p) paint, (g) ground, (s) size, (c) canvas. Image: © Mary Piper Hough and Stefan W. Michalski

By combining equations from geometry with Timoshenko's equation for curvature of a two-layer laminate (Timoshenko 1925), we can derive the height of the curl in the paint-ground laminate.[2] Height depends on the difference in shrinkages, the thickness of the laminate (in this case, paint and ground), and the width (w) of the region that is free to curl. The inset graph in figure 40.1 shows cupping height (y-axis) for various laminate thicknesses (x-axis), for paintings where the paint layers are equal to, or not more than a few times thicker than, the ground, and are not especially soft compared to the ground.[3] Plots are shown for a range of differential shrinkages, with 0.2% as a difference we can expect for an oil paint on a lean ground, whether oil or acrylic.[4] The blue circle marks the predicted curl for the model paintings in this study. Much larger shrinkages due to severe aging or solvent leaching will drive much larger curl.

The size layer is not considered in this model for curl (equations for a three-layer system are beyond the scope of this paper). However, one can expect shrinkage of the size layer to counteract shrinkage of the paint layer, especially at low humidities, but in Hough's measurements of curl in the experimental samples (see "Profile Measurement" below), curl definitely increased with lower RH (Hough 2000, fig. 11),[5] showing that shrinkage of the paint layer dominated shrinkage of the size layer. We can qualify this simple two-layer model for curl, paint-ground, as an estimate of the maximum expected curl.

Where the painting is cracked, the canvas acts as a hinge (fig. 40.1b). Curl is then limited by the surrounding area of the painting plus any overall tension. If the painting is keyed out, the canvas hinge and the cupping are pulled toward flatness, but this flattening reaches a limit when the canvas hinge aligns with the center of the tension located in the size, ground, and paint layers of the uncracked regions.[6] Cupping cannot be flattened beyond this limit no matter how much tension is applied. This flattening limit h_{align} is equal to at least half the combined thickness of canvas, size, and ground (for low-stiffness paint) and at most half the combined thickness of canvas, size, ground, and paint (for high-stiffness paints). In figure 40.1b, the simplest situation has been assumed, where the red line is in the middle of the size-ground-paint laminate.

Surfacing Mechanisms

If a reinforcement is added to the verso and if the painting has zero tension, then the result shown in figure 40.2a is plausible. In a painting with some tension (driven by keying out, gravity, or low humidity), the reinforcement will surface with a profile somewhere between the two extremes: a ridge if the reinforcement behaves like a chain (fig. 40.2b), or a plateau if the reinforcement behaves like a plate (fig. 40.2c). Additional distortions may be superimposed if there is differential swelling or shrinkage driven by heat, plasticizer, solvents, moisture, or an adhesive.

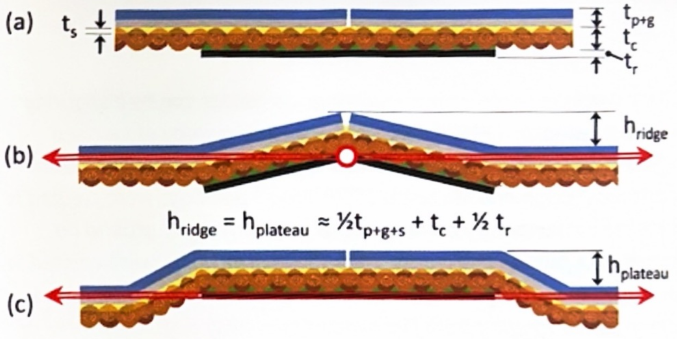
(a)
t_s
t_{p+g}
t_c
t_r
(b)
h_{ridge}
$h_{ridge} = h_{plateau} \approx ½t_{p+g+s} + t_c + ½\, t_r$
(c)
$h_{plateau}$

Figure 40.2 The three conformations of a locally reinforced crack when under tension. (a) The desired state, when paint and reinforcement are completely inflexible (plate-like). (b) Ridge surfacing, due to stress alignment of a flexible reinforcement (chain-like) with a flexible painting (chain-like). (c) Plateau surfacing, due to stress alignment of a rigid reinforcement (plate-like) with a flexible painting (chain-like). Subscripts: (p) paint; (g) ground; (s) size; (c) canvas; (r) reinforcement. Image: © Mary Piper Hough and Stefan W. Michalski

The deformations shown in figures 40.1 and 40.2 are not static; they can only be measured and understood within the framework of viscoelastic mechanics; that is, one must consider time. Large elastic deformations of paints can be accomplished in as little as seconds when high temperature and plasticizer are used, whereas at room temperature, large elastic movements take months or years. On the one hand, trying to bend a paint film quickly at room temperature will fracture it; on the other hand, successfully flattened paint can recover the memory of its old deformation over the course of months and years. (For a theoretical background, see papers in these proceedings by Hagan and by Daly-Hartin, Michalski, and Hagan.)

To maintain flatness over the years, a reinforcement must stress relax much more slowly than the paint layers. This suggests that one should select either inorganic materials (metal, glass) or highly cross-linked, filled polymers.

Butt Joints

Theoretically, the ideal solution to cupping at a crack would be to repair the crack itself—to make a butt joint. It is, unfortunately, extremely difficult in practice to make a butt joint that is continuous, reliable, and invisible.

EXPERIMENTS

The aims of the study were as follows:

- Make cracked model paintings that exhibit significant cupping
- Subject the cracks to local treatments, orthodox and novel, that attempt to flatten cupping and restrain its reappearance
- Document the cupping heights of the cracks as a function of time
- Determine which treatments, if any, are visually acceptable
- Apply the models of viscoelastic mechanics to the interpretation of the results

Preparation of Model Paintings

The model paintings follow a technique often used by artists from 1950s onward: oil paint on acrylic ground on cotton duck fabric. One or more localized disfiguring cracks have often been observed in such paintings. Nine paintings were prepared on commercial stretchers, 61 × 168 cm (24 × 66 in.), in landscape orientation. Two wide, vertical crossbars were rigidly attached to the top and bottom stretcher bars, so that tension could be released in the horizontal axis without disturbing the vertical axis. The corners of the stretcher were expanded 6 mm in each direction prior to application of the canvas, to permit slackening when needed.

After stretching the cotton duck, the perimeter was masked to create a 7.6 cm (3 in.) border of uncoated fabric. This flexible border reduced tension in the painted area, simulating the large slack paintings that were the focus of the study. The cotton was coated with three layers of acrylic ground, followed by six layers of lead white/zinc white oil paint. The total thickness of the ground roughly equaled the thickness of the paint. All layers were monitored by weight to ensure uniform application.

Cracking and Heat Aging of Model Paintings

To create multiple uniform cracks, a guillotine-like apparatus was made. The apparatus and painting were kept in a cold room at −5°C (±2°C) to ensure brittle, glassy behavior during impact. The painting was placed facedown over a narrow trench, and the dull blade was dropped. The amount of indentation was limited by an adjustable stop to avoid plastic deformation. Nine 15 cm (6 in.) cracks were created in each painting, parallel to the short dimension and spaced evenly along the long dimension. Fairly consistent, clean fractures with very little distortion of the canvas were obtained.

The paintings were keyed in to slacken them in the direction perpendicular to the cracks to facilitate curl. They were then heat aged for nineteen days at 41°C to speed any curing and relaxation processes prior to treatment (fig. 40.3).

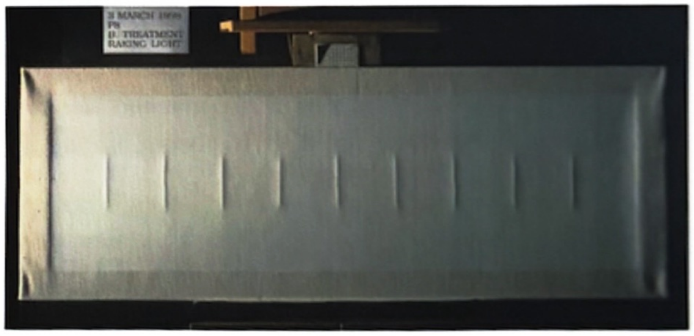

Figure 40.3 Raking-light image taken before treatment of one of the model paintings. Each of the nine cracks was slackened in the direction perpendicular to the cracks to facilitate curl. The raking light used in this photograph at the beginning of the testing was less extreme and less sharp than that used in subsequent figures. Image: © Mary Piper Hough and Stefan W. Michalski

Experimental Treatments

Of the fourteen local treatments tested, one included moisture and heat alone with no reinforcement; others included various sizing or adhesive methods, and eight were variations on the application of thin reinforcing strips adhered across the crack verso. Two implausible treatments using rigid plates applied to the crack verso were tested to establish baseline "flatness" data. Some treatments were derived from those in use at the time in the local treatment of cupped cracks or of tears; others were experimental designs. Variation in the resulting degree of stiffness was a main reason for choosing a treatment to see its ability to hold the cupping flat. Important also were the application from the verso, especially for paintings with sensitive surfaces, and the ease of removability of the added reinforcement. The treatments varied in the location of the added element, the adhesive, the reinforcement, or both, some of which have consequences for surfacing.

During treatment, the painting was placed facedown, and each crack was held flat for about thirty hours using a purpose-built suction table. For most treatments (2–11), the reinforcement was applied to the crack verso while the crack was held flat under suction. Eight simple suction tables were made to allow multiple treatments to be performed in one day, since pressure needed to be maintained for drying or curing.

All the strips of material used in treatments 4–11 were fabricated so that their thickness was the same (0.50 mm ± 0.05 mm). This thickness was fixed by the stainless-steel strips of treatment 4 (0.48 mm). Width varied between 0.64 mm (stainless-steel strips) and 2 mm. Various casting and molding techniques were employed, and a micrometer was used to check thicknesses. Strips 8 and 9 (wet treatments) were molded in situ, with steel strips present as thickness gauges. All strip treatments were applied across the crack verso and were spaced at 3.2 mm (1/8 in.) intervals, with alternating lengths of 25.4 mm and 12.7 mm (1 in., 1/2 in.), except treatment 8. Verso images of some treatments are shown in figure 40.4.

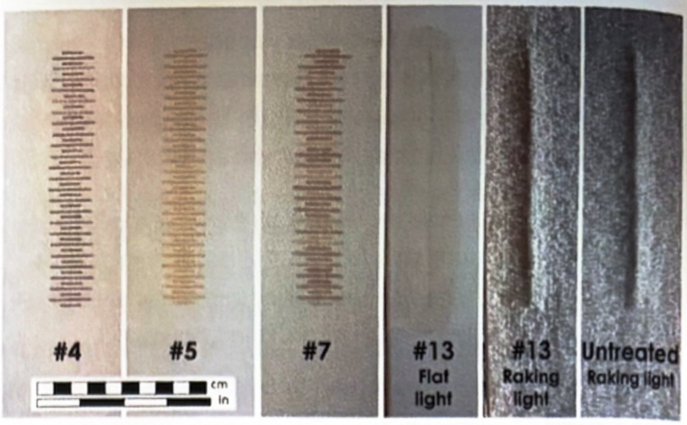

Figure 40.4 Verso images of four treated cracks showing strips (treatments 4, 5, 7) and size (treatment 13). Raking-light images show cupping of canvas for 13 and an untreated crack. Image: © Mary Piper Hough and Stefan W. Michalski

Details of each treatment are as follows:

1. Moisture, heat, and flattening; no reinforcement. Moisture was applied to the crack area at recto using damp, felted Gore-Tex for twenty-four hours, followed by suction from recto and heat from verso.
2. Acrylic plate, 3.2 mm thick, applied to the canvas over a wide area with five-minute epoxy. This was a benchmark reinforcement for experimental purposes, not a suggested treatment for paintings.
3. Epoxy/aluminum foil plate, 50 mm wide, attached with two layers of Beva 371 film.[7] This was an exploratory treatment designed to test the behavior of very thin aluminum composites and continuous patches.
4. Individual stainless-steel strips (0.48 mm × 0.64 mm orthodontic "wire" with rectangular cross-section); attached with two layers of Beva 371 film.
5. Strips made of Epoweld 3672 epoxy filled with full-length glass filaments (50 μm diameter), oven-heated to improve curing of the epoxy; attached with two layers of Beva 371 film.
6. Strips made of polyester threads coated with epoxy (Epoweld 3672), oven-heated; attached with two layers of Beva 371 film.
7. Strips made of polyester threads coated with epoxy (Epoweld 3672), allowed to cure at room temperature; attached with two layers of Beva 371 film.

8. Strips made of polyester threads coated with epoxy (Epoweld 3672), applied wet to the crack verso. Four variations on thread length and spacing were tried.
9. Strips made of polyester thread coated with PVA (Jade 403), applied wet.
10. Beva 371 size (1:1 naphtha) applied to verso of the crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. Strips from treatment 6 were attached with two layers of Beva 371 film.
11. Acryloid B-72 size (20% in xylene) applied to verso of crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. Strips from treatment 6 were attached with two layers of Beva 371 film.
12. Beva 371 size (1:1 naphtha) applied to verso of crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. No reinforcement.
13. Acryloid B-72 size (20% in xylene) applied to verso of crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. No reinforcement.
14. Epoxy (EPO-TEK 301) flowed into the crack from the recto to adhere the two fracture faces in a butt joint. Unlike in treatments 1–13, suction was applied from the verso by a Mitka suction table with the painting faceup. Then a hard, flat weight was applied over the crack area for twenty-four hours.

Profile Measurement

In the first phase of the study, the profiles of each crack were scanned using a mechanical scanner developed for this project. The scanner provided a profile of a 20.5 cm (8 in.) line perpendicular to the center of the crack, with a sensitivity of about 1μm in height. Unfortunately, over the years the scanner had been discarded, so for the height measurements at twenty-one years, we used calibrated raking-light photographs. Calibration was made using a 0.6 mm leaf from a feeler gauge, held firmly below each crack by magnets behind the painting.

For further information on the experimental methods and materials, and initial results for the slack painting condition, please refer to our article (Hough and Michalski 1999) or Hough's thesis (Hough 2000).

Taut Painting Condition

A year after the first stage of the project ended, three paintings that contained at least one of almost all the treatments were keyed out in order to study the taut condition where cupping is driven by stress alignment rather than curl, and to study the tendency of the repairs to surface. To ensure reproducible movement, a central crossbar was added to the long dimension, with adjustable turnbuckles that controlled tension perpendicular to the cracks (fig. 40.5). The arrangement of the nine cracks in a row ensured that even if carefully calibrated keying out did not yield exactly the same tension across all paintings, at least within each painting, samples would be subject to equal tension and could be compared directly and reliably.

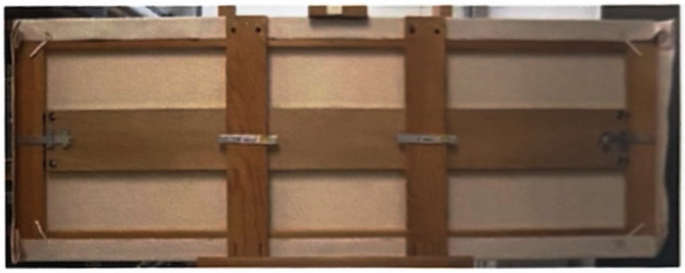

Figure 40.5 Verso of a model painting that was keyed out. Vertical crossbars were present on all paintings. The horizontal crossbar with turnbuckle expansion bolts at each end was added to paintings that were keyed out. Sliding metal guides at each end prevented twisting of the vertical stretcher bars. Image: © Mary Piper Hough and Stefan W. Michalski

RESULTS

Results for each treatment are summarized in table 40.1 and presented visually in figures 40.6 and 40.7. Cupping heights over time for all treatments are plotted in figure 40.8. Here, only the highlights are noted, with further detail provided in the Discussion section.

Table 40.1

Summary of treatment results

Treatment					Results: Visual appearance of crack in raking light (time after treatment)			
	No.	Size	Reinforcement	Adhesive	Painting slack (70 days)	Painting slack (21 years)	Painting taut (21 years)	Images (21 years)
Moisture and heat	1	Moisture, heat + flattening alone. No size, no reinforcement, no adhesive			Initially 1/2 height; in a few days, approached before-treatment height with more gradual slope; at 2 months, original steeper slope reappeared: crack profile narrowed + aperture opened	Crack has the appearance of an untreated crack	Crack has the appearance of an untreated crack; cupping height lower than in slack painting	Fig. 40.7
Plates, for reference	2	—	Acrylic, 3.2 mm	Epoxy	Crack appeared flat; plate perimeter surfaced	Same as 70 days after treatment	NA—not keyed out	Fig. 40.7
	3	—	Epoxy/ aluminum foil, 0.3 mm	Beva 371 film	Crack appeared flat; plate perimeter surfaced	Crack has slightly raised; surfacing still present	NA—not keyed out	Fig. 40.7
Strips	4	—	Stainless-steel strips	Beva 371 film	Crack slightly raised	Crack raised slightly higher; no surfacing	Same as for slack painting	Figs. 40.4, 40.6, 40.7
	5	—	Epoxy/glass filaments; heat cured	Beva 371 film	Crack slightly raised	Crack still appears slightly raised; no surfacing	Crack remains slightly raised; however, now with surfacing due to bending of strips; gradual slope	Figs. 40.4, 40.7
	6	—	Epoxy/ polyester threads; heat cured	Beva 371 film	Crack slightly to moderately raised; epoxy heat curing appears significant in stiffening compared to treatment 7	Crack is moderately raised; no surfacing	Crack appears moderately to fully raised; surfacing is present	Fig. 40.7
	7	—	Epoxy/ polyester threads; room cured	Beva 371 film	Crack moderately raised	Crack is moderately raised, height higher; no surfacing	NA—not keyed out	Fig. 40.4
	8	—	Epoxy/ polyester threads; room cured	Threads applied wet	Crack slightly raised; epoxy flowed intermittently into crack for greater height control, resulting in stitched appearance	Crack moderately to fully raised; stitched appearance; no surfacing	Cupping height is lower than in slack painting; stitched appearance; surfacing is present	Figs. 40.6, 40.7
	9	—	Jade 403/ polyester threads	Threads applied wet	Initially 1/2 height; in a few days, approached before-treatment height with gradual slope; at 70 days, original steeper slope reappeared	Crack has appearance of an untreated crack; no surfacing	NA—not keyed out	Fig. 40.7
Size + strips	10	Beva 371, heat	Epoxy/ polyester threads; heat cured	Beva 371 film	Crack was slightly raised; slight moating in sized area	Crack is slightly to moderately raised; strong	Crack approaches appearance of untreated; keying out removed appearance	Figs. 40.6, 40.7

Treatment					**Results: Visual appearance of crack in raking light (time after treatment)**			
	No.	**Size**	**Reinforcement**	**Adhesive**	**Painting slack (70 days)**	**Painting slack (21 years)**	**Painting taut (21 years)**	**Images (21 years)**
						moating, no surfacing	of moating; surfacing present	
	11	B-72, heat	Epoxy/ polyester threads; heat cured	Beva 371 film	Crack appeared moderately raised; strong moating in sized area	Crack is slightly to moderately raised; severe moating, no surfacing	Crack approaches appearance of untreated; slight moating is visible; surfacing present	Fig. 40.7
Size alone	12	Beva 371, heat	—	—	Crack appeared slightly to moderately raised; sized area was moderately moated	Crack has appearance of untreated; slight moating is visible: no surfacing	Cupping height is lower than in slack painting; moating not apparent; no surfacing	Fig. 40.7
	13	B-72, heat	—	—	Crack appeared to be half of before-treatment height; sized area was severely moated	Crack has appearance of untreated; strong moating is visible; no surfacing	Cupping height is lower than in slack painting; moating is minimized; no surfacing	Fig. 40.7
Butt joint	14	—	—	Epoxy butt joint	Crack appeared moderately raised	Crack appears moderately raised; no surfacing	Crack appears moderately raised; no surfacing	Figs. 40.6, 40.7

Table: Mary Piper Hough and Stefan W. Michalski

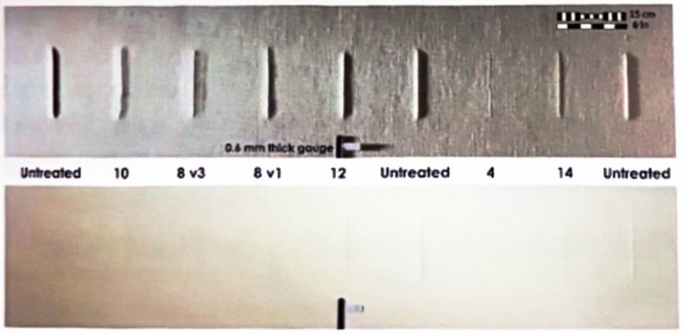

Figure 40.6 Two photographs of a painting that contains a sample of treatment 4, the most successful of those tested, taken 21 years after treatment and 20 years after keying out. Top: raking light 1:40 from the left. Bottom: 30-degree lighting from the left. Image: © Mary Piper Hough and Stefan W. Michalski

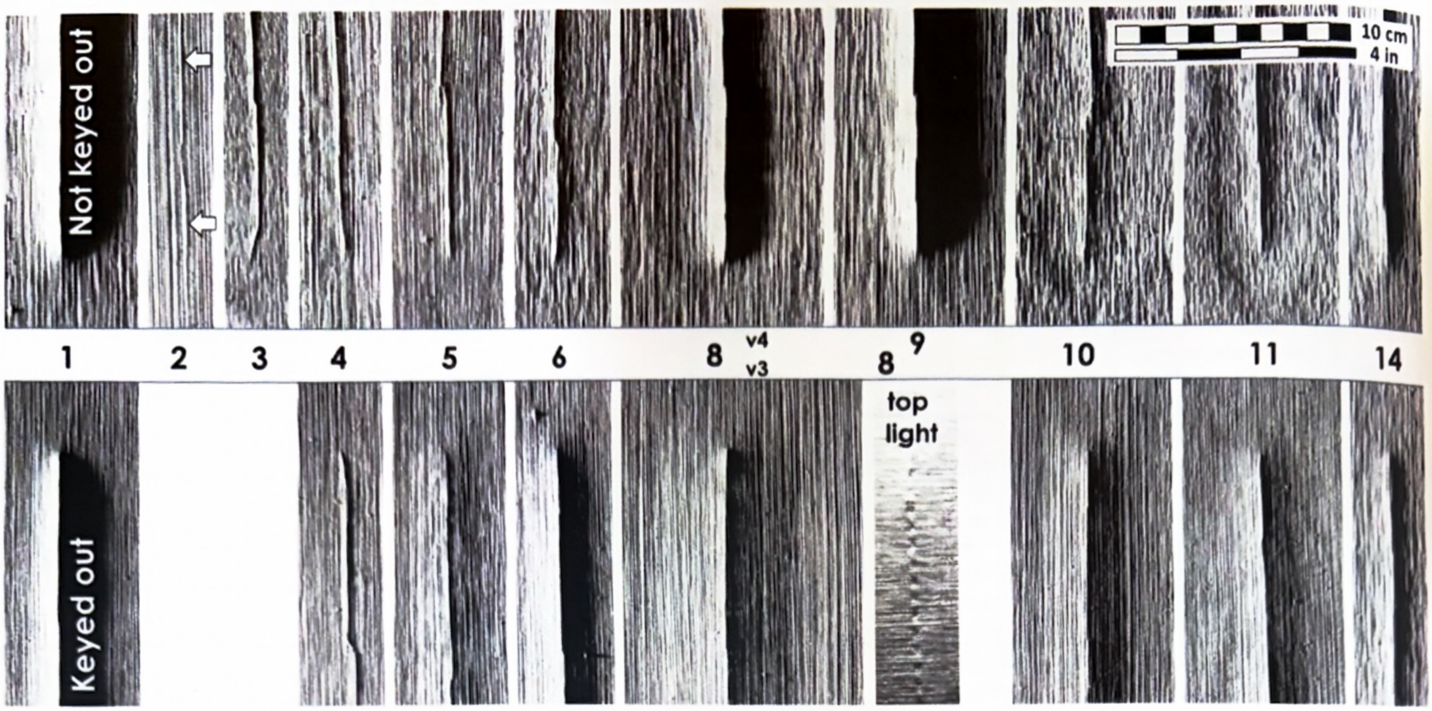

Figure 40.7 Raking-light close-ups of individual treated cracks after 21 years. Top row: samples in slack paintings. Bottom row: the same treatments in taut paintings (keyed out 20 years ago). For clarity, the images have been changed to grayscale and their contrast increased. Image: © Mary Piper Hough and Stefan W. Michalski

During the early monitoring of the cracked model paintings, prior to any treatment, cupping increased after the tension was released, exceeding the painting's half thickness, thus confirming curl as the dominant driving force (Hough and Michalski 1999, fig. 7).

After the first seventy days, before any keying out, only three of the treatments (4, 5, 6) were successful in terms of visual appearance—rigid enough to hold the cupping down and insubstantial enough not to create new distortions.

After twenty-one years of being slack, only 4 and 5 remained visually acceptable, and no surfacing was present (see fig. 40.7, top row).

After twenty years of being taut (keyed out), many treatments showed pronounced ridge surfacing (see fig. 40.7, bottom row). Only 4 was successful: it held the cupping almost flat but did not provoke plateau surfacing. One of the treatment 4 samples is shown in figure 40.6, alongside other treatments as well as untreated cracks within a single painting.

For treatment 8, the epoxy was allowed to set up for a period before the suction was turned on. Despite this time allowance, the suction pulled the epoxy into the crack face, partially closing the crack and holding it flat intermittently—resulting in a partial (inadvertent) butt joint. This is visible when raking light comes from above, as in figure 40.7, bottom row: the crack has a stitched appearance and a comb-like shadow.

The cupping in the untreated cracks reached heights of ~0.7 mm in the slack paintings. In the keyed-out paintings, the cupping reached only ~0.51 mm, less than in the slack paintings, as expected (see fig. 40.1). On the verso, the canvas has followed the curling paint layers. No delamination was noticed in any of the samples.

DISCUSSION

Final States of Treatments after Twenty-One Years

In terms of the predictions of curl (see fig. 40.1a), given the ~0.38 mm thickness of paint and ground for the model painting, assuming a region for unrestrained curl about 20 mm wide on each side of the cracks, and assuming the shrinkage differential between oil paint and acrylic ground of 0.2% estimated earlier, the result places the blue circle in the inset graph in figure 40.1, predicting a cupping height of ~1.6 mm. The average cupping height of untreated cracks in slack paintings, 0.68 mm, is less than half of this estimate, implying either that the estimate of shrinkage is too high or, more likely, that the canvas hinge (and perhaps the size) is restraining curl.

In terms of the predictions of stress alignment without reinforcements (see fig. 40.1b), given the thickness of the paint and ground, ~0.38 mm, and the canvas thickness of ~0.76 mm, then by the equation in figure 40.1b, we expect untreated, heat/moisture-treated, or size-treated cracks to have cupping height of ~0.57 mm. Untreated cracks in taut paintings (three samples) reached 0.51 ± 0.02 mm. If we estimate that half the ground sank into the canvas weave, then the prediction falls to ~0.52 mm, as observed. The cupping of heat/moisture treatment (1) reached 0.45 mm, 12% lower than untreated cracks, while size treatments (12, 13) reached 0.35 mm, 31% lower.

Keying out created ridge-shaped surfacing in all treatments that used reinforcements, except treatment 4, the steel; that is, all polymer reinforcements and the glass bundles embedded in a polymer bent at the crack, thus reating a ridge, as shown in figure 40.2b. Keying out generated consistent ridging heights: worsening eatments that did well when slack (except treatment 4), nd improving treatments that had maximum curl when slack.

Both the ridge surfacing caused by reinforcements under tension and the moating[8] caused by size treatments were precisely aligned with their location on the back of the canvas. There was no complex extension of visible deformation beyond the boundaries of the verso treatment.

In terms of the predictions of surfacing of reinforcements (see figs. 40.2b, 40.2c), given the thickness of all reinforcements of 0.50 ± 0.05 mm and the paint, ground, and canvas thicknesses specified earlier, we expect the height of surfacing to be ~1.2 mm (only ridge surfacing was observed). Heights for reinforced treatments using polymers (6, 8) ranged between 0.35 mm and 0.30 mm, respectively (see fig. 40.8, graph on right, top). The glass fiber reinforcement (5), while successful in a slack painting, surfaced as much as the polymer reinforcements when taut: 0.35 mm. None of the ridge surfacing of reinforcements reached the prediction of stress alignment; all remained at or below 0.45 mm, about a third of our prediction. This suggests that the treatments, although visually unacceptable, had functioned to some extent as intended. From another perspective, it is suggested that the tension applied by the keying out was not severe enough to achieve maximum surfacing.

Only one mystery remained: since the stainless-steel strips, treatment 4, did not bend at the crack, why did they not surface as a plateau instead? The simplest answer is that the amount of tension we provided by keying out was not enough to bend the paint and ground into the S shape required at each edge of the surfacing plateau of figure 40.2c. This is consistent with the conclusion that the tension in the keyed-out paintings, while enough to drive some ridge surfacing of polymer reinforcements, was not enough to drive the maximum predicted. In other words, the keyed-out paintings were tight enough to cause ridge surfacing of flexible reinforcements, but not sufficient to cause noticeable plateau surfacing. Unfortunately, the raking-light measurement method did not show small, gradual profile changes that more sensitive scanning might have detected. Perhaps our expectations of plateau surfacing were biased by observation of old patches that employed generous amounts of glue. These generate huge forces during low humidity, independently of keying out, and are much thicker than the reinforcements we used.

Viscoelastic Response over Time

In the graph on left in figure 40.8, we can follow the viscoelastic behavior of the treatments that were never keyed out, starting at five minutes after they were released from the suction table up to twenty-one years later. This type of graph—the logarithm of an elastic measurement versus the logarithm of time (a log-log plot)—is conventional in viscoelastic studies of polymers, because it can be placed in the context of master curves, as described elsewhere in these proceedings by Daly Hartin et al. and by Hagan. The heavy gray line at the top of the graph on left in figure 40.8 shows the slope of the master curve for stress relaxation of oil paintings measured by Daly Hartin et al. for the range of five minutes to one hundred years, which was 1/13, that is, 1 log unit in height for each 13 log units of time.[9] The overall slope of the treatments that failed (and allowed the cupping to return) is similar to this slope. Even sized samples with a rapid increase in cupping in the first few hours followed by a striking decrease that lasted several months (treatments 10, 11, 12, 13), did return over the years to an overall slope of ~1/13, if one simply considers the first and last data points.

Treatment 1 (heat and moisture) also shows a small wobble in its plot, though not as pronounced as that of the sizes. This plateau between a few days and a few months led us to believe in our 1999 paper that this was a final plateau, but over the last twenty-one years it has returned to its initial rate of climb and reaches just short of completely untreated cracks.

The spread in the five-minute data points shows the diminishing springback of cupping immediately[10] after the suction pressure was released. As expected, heat and moisture without reinforcement (treatment 1) has the

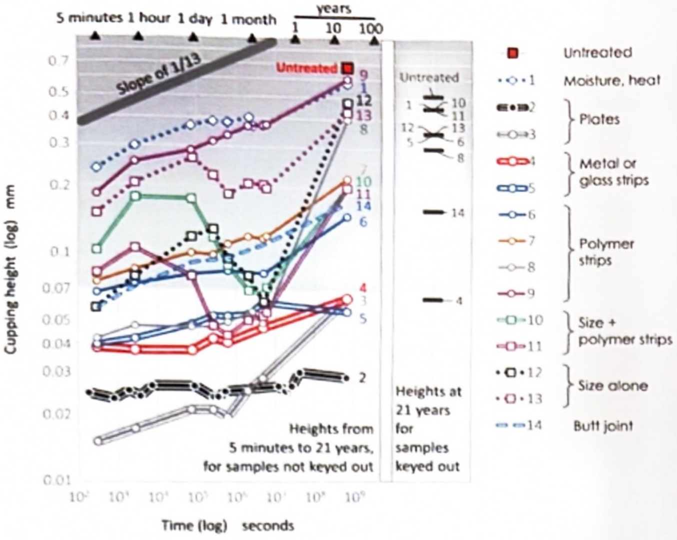

Figure 40.8 Cupping height from five minutes to 21 years. Graph on left shows growth over time for treatments in slack paintings. Graph on right shows single data points for treatments in taut paintings that were keyed out 20 years ago. Gray region indicates heights that are noticeable under normal 30-degree lighting. Image: © Mary Piper Hough and Stefan W. Michalski

largest springback, about one-third of the twenty-one-year cupping; by the first month, the second third recovers. Treatment 9 behaves similarly—demonstrating that a non-cross-linked polymer with a low glass transition temperature, such as the PVA (Jade 403), offers negligible resistance. The benefits, if any, of such treatments are transitory. Remaining five-minute data points are in the expected order of increasing stiffness and less springback: polymer, then glass, then metal.

Since glass fibers (treatment 5) do not relax, the epoxy matrix binding them must have relaxed by shearing between filaments.

The difference between treatments 6 and 7 shows the benefits of heat-curing the epoxy to decrease its relaxation.

The butt joint (treatment 14), although not perfect in adhesion, kept the cupping at around a quarter of untreated heights throughout the duration, while climbing at the master slope of ~1/13.

The benchmark plate treatment (2), which within experimental error can be considered a flat line, demonstrated that it is possible to hold the cupping completely flat with a thermoset adhesive that soaks into the canvas and is cemented to a thick, rigid plate. It also established that the suction table could hold the cupping flat to within 0.025 mm on all treatments prior to release of the suction. The thin aluminum foil treatment (3) did not appear to bend either, but it did allow small cupping to emerge over the twenty-one years, as did treatments 4 and 5. All three showed very slow climbs toward a similar, nondisturbing height at twenty-one years. These cuppings are extremely low and narrow, and although the canvas could easily be seen to follow the large deformations of unsuccessful treatments, it was not possible to determine if the back of the canvas had followed exactly these very small deformations. A cupping height of 0.06 mm is only 8% of the thickness of the canvas (0.76 mm), so a slight bulging of the canvas threads would be enough to allow this curl of paint, and even if Beva entered the threads, as a thermoplastic it could certainly flow over the decades, allowing the canvas to bulge.

CONCLUSIONS

Our conclusions fall into two categories: those that have practical ramifications and those that are more theoretical.

Practical Conclusions

- The application of a local adhesive in solvent (naphtha or xylenes) as a size (treatments 10–13) results in distortions (moating) that do not completely disappear.
- Surfacing of local reinforcements is driven by tension in the painting. Ridge surfacing of flexible reinforcements occurs at lower tension than plateau surfacing of rigid reinforcements (assuming paintings with similar structure to our model painting, or those with even thicker paints or grounds).
- Keeping the first two conclusions in mind, good results are possible if the reinforcement, such as metal, does not stress relax; if it is thin, such as very thin stainless-steel strips (treatment 4); if it is spaced and feathered; and finally, if the painting is under only moderate tension.
- The neatest theoretical solution to both cupping and surfacing would be to adhere the fracture faces in a butt joint. Treatment 14 showed moderately good control of cupping. This treatment may eventually fail, but at least it will never surface. For this reason alone, more study of this option is warranted.
- Data on samples before treatment showed that low RH substantially increases curl (Hough 2000). Low RH also drives overall tension in a painting. Therefore, low RH will drive curl in slack paintings and surfacing in taut paintings.

- Careful lighting can reduce the visibility of cupping.

Theoretical Conclusions

- The slow return of cupping over time is the result of viscoelastic phenomena that are consistent with the master curves for paintings presented by other authors in these proceedings.
- In taut paintings, cupping of untreated cracks or treatments not using reinforcements was consistent with the model predictions for stress alignment.
- In taut paintings, ridge surfacing of reinforced paintings was less than the maximum predicted, indicating that all reinforcements resisted bending to some degree at the level of tension used.

NOTES

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1. *Surfacing* refers to the development at the surface of a painting of a deformation that corresponds to the shape of a local repair applied to the verso of the painting, such as a patch.
2. Timoshenko derived the curvature of any two-layer laminate with differential shrinkage. If the differential shrinkage is $(\varepsilon_1-\varepsilon_2)$, m is the ratio of the two thicknesses, n is the ratio of the two moduli of elasticity, and t is the laminate thickness, then radius of curvature is R=(t*(3*(1+m)^2+(1+m*n)*(m^2+1/(m*n))))/(6*$(\varepsilon_1-\varepsilon_2)$*(1+m)^2). The height h of the arc over a base of w and curvature R is h=R-(R^2-w^2). See https://www.mathopenref.com/sagitta.html.
3. Given initial values of m=n=1 (see note 2) a plot of h stays within 25% of initial value despite changes in thickness ratio, n, by a factor of 3, or changes in elasticity ratio, m, by a factor of 7. Heavy impasto, or paints known to be soft, such as poor driers, will need the full equation, rather than the inset graph in figure 40.1.
4. Curing shrinkage of linseed oil was suggested as a contributor to paint failure as early as 1929 (Clark and Tschentke 1929). Pure medium with driers, cured in the dark, shrank 1%–1.6% by volume, so 0.3%–0.5% in length. A paint of 35% pigment volume concentration (PVC) would experience ~65% of pure oil values, so ~0.2–0.3%. A ground at critical PVC would shrink negligibly in comparison. Browne reported dimensional change for films of linseed oil paints after they were released from the casting substrate and exposed to cycles of high RH (Browne 1955). Michalski plotted the nonrecoverable shrinkage from Browne's data: ~0.3% for an oil paint of 30% PVC, consistent with Clark and Tschentke (Michalski 1991, n25).
5. Since the RH in the room where cupping was measured varied gradually over the course of the study, all cupping heights prior to treatment were plotted versus RH in order to derive a correction factor to normalize results to 50% RH. The factor was 2.1% height increase per 1% RH drop, for example, 21% height increase when RH is reduced from 50% to 40% RH (slack paintings).
6. The stress-alignment concept was introduced to our field in an unpublished report by Marion Mecklenburg. His original term was "force realignment" (Mecklenburg 1982).
7. The original formulation of Beva was used in all experiments.
8. Moating is the development of a depression resembling a moat in a treated area of the painting, in this case, a depression encircling the crack.
9. The slope of the stress relaxation is actually negative 1/13, the mirror image of the +1/13 of creeping of cupping.
10. There is no "immediate" time zero in viscoelasticity; the springback would have occurred during several milliseconds as the suction pressure decreased, and with the correct tools one could have measured cupping heights growing from those milliseconds forward to our first data point at five minutes. Milliseconds would enter the glassy plateau shown by Daly Hartin et al. for millisecond events.

46

Historical Canvases Deciphered: Five Case Studies

Helena Loermans, Lab O, Odemira, Portugal

Textiles with a woven pattern were used as painters' canvases by Spanish and Italian artists in the sixteenth and seventeenth centuries. In this poster, textiles that have been hidden for centuries between paint and lining canvas come to life in handwoven reconstructions. The research and reconstruction of canvases contributes to the understanding of technical painting and art history and brings attention to an understudied aspect of textile production during the period that an artwork was created. Canvas reconstruction enables new research and may provide insight into why old masters used these supports, as well as how and when these textiles were made.

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INTRODUCTION

Textiles with a woven pattern were used as painters' canvases by Spanish and Italian artists in the sixteenth and seventeenth centuries. But art historians and paintings conservators have focused on the painted layers rather than on the underlying fabric.

In this poster, textiles that have been hidden for centuries between paint and lining canvas come to life in handwoven reconstructions of the support canvas of five paintings by El Greco (fig. 46.1), Titian (fig. 46.2), Caravaggio (fig. 46.3), and Velázquez (figs. 46.4, 46.5). The support canvas used by the great masters is shown in each of the figures.

MATERIAL AND METHODS

Close examinations enabled Lab O to analyze the weave structure of the patterned textile canvas. Using software developed for computer-aided handlooms, Lab O then developed a weave draft for the reproduction of these linen textiles.

A weave draft of the El Greco canvas had already been published (de los Rios y Rojas and Socorro 1977). Four high-resolution X-ray images, provided by the museums that hold the paintings, were deciphered to find the pattern of these textiles.

After consulting the first published book on weaving (Ziegler 1677) and a modern facsimile, translation, and study (Hilts, Ziegler, and Lumscher 1990), a weave draft was generated for each textile using software developed to interface with computer-aided handlooms.

All reconstructions were then woven in linen on a dobby loom.

THE PROJECT GOAL

Lab O, a laboratory for handwoven canvas located in Odemira, Portugal, was founded to deepen the technical and practical knowledge of historical canvases and to promote their analysis, authentication, and conservation. The work at Lab O connects craft, entrepreneurship, technology, science, and art history.

The research and reconstruction of canvases contributes to the understanding of technical painting and art history and brings attention to an understudied aspect of textile production during the period that an artwork was created. Canvas reconstruction enables new research and may provide insight into why old masters used these supports, as well as how and when these textiles were made.

El Greco

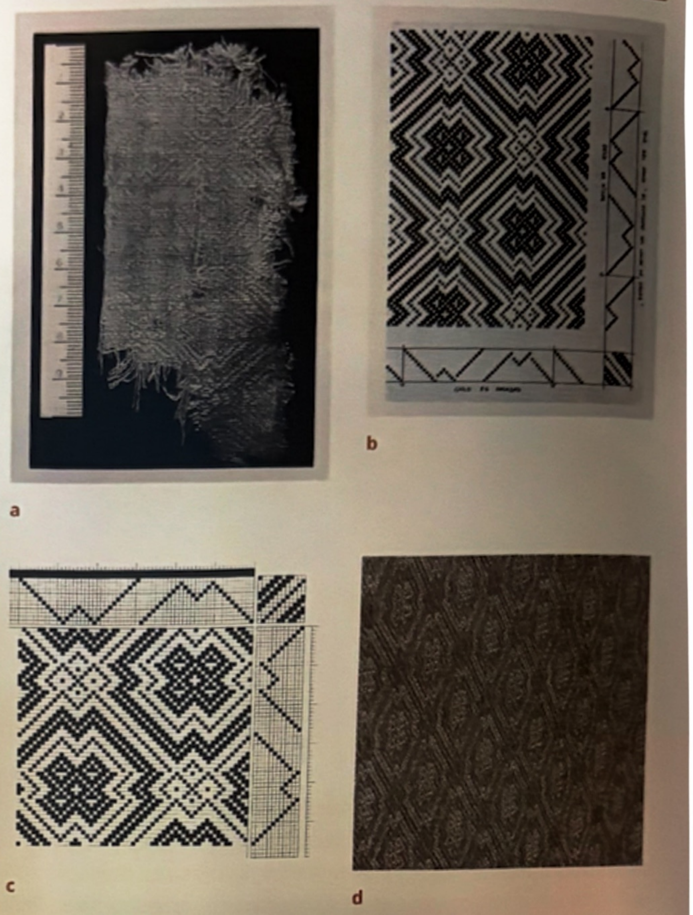

Figure 46.1 El Greco (Greek, 1541–1614), *The Burial of the Count of Orgaz*, 1586. Oil on canvas, 480 × 360 cm (189 × 141 3/4 in.). (a) Piece of original canvas showing weave pattern. (b) Weave draft (de los Rios y Rojas and Socorro 1977). (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a and b) de los Rios y Rojas and Socorro 1977, (c) Lab O, (d) Lab O / João Mariano

Titian

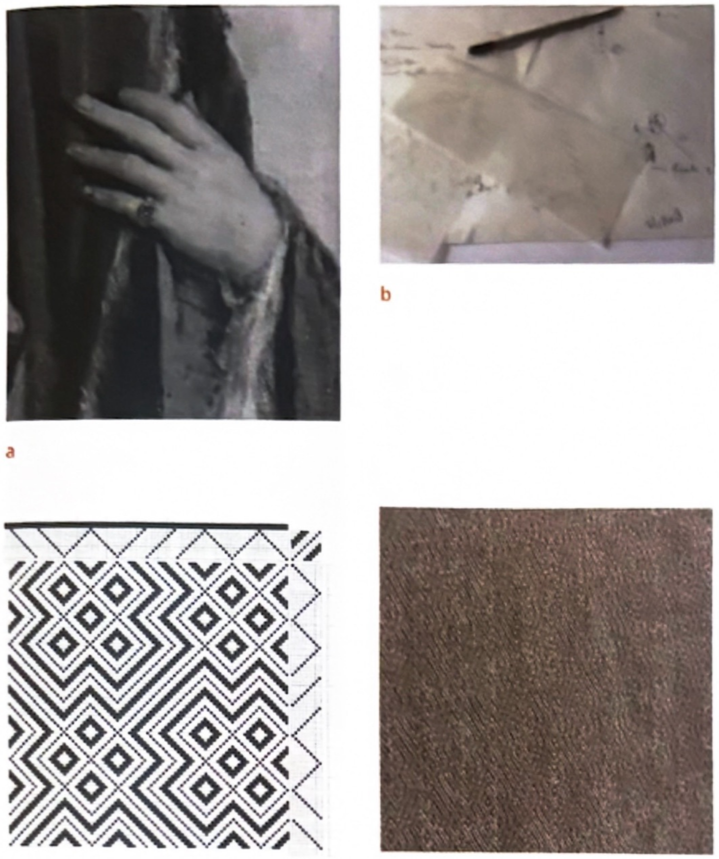

Figure 46.2 Titian (Italian, ca. 1488–1576), *The Vendramin Family*, 1540–45. Oil on canvas, 206 × 288.5 cm (81 1/8 × 113 5/8 in.). (a) Detail of Gabriel's left hand before cleaning and after retouching. (b) Handmade drawing of the pattern. (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a) National Gallery London, (b and c) Lab O, (d) Lab O / João Mariano

Caravaggio

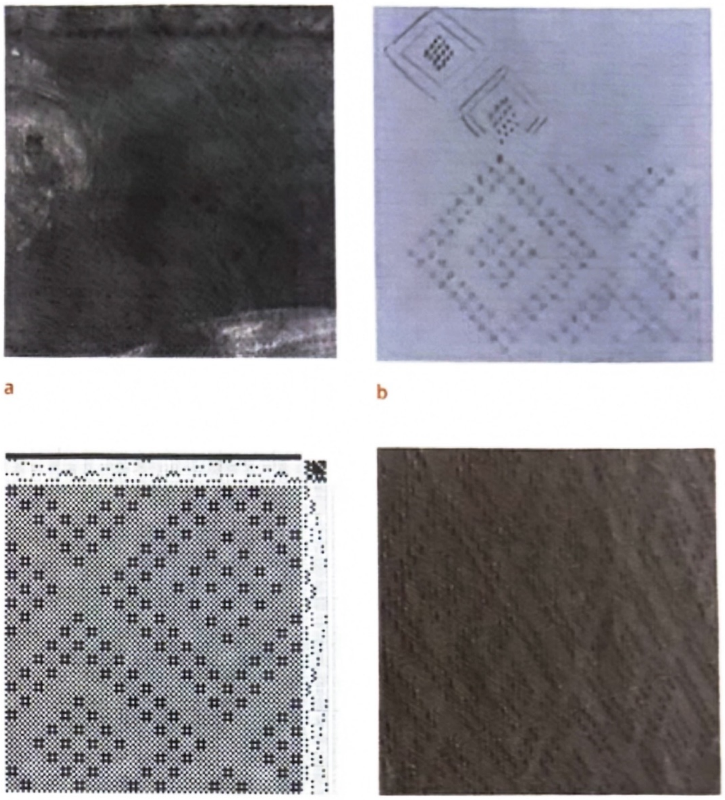

Figure 46.3 Caravaggio (Italian, 1571–1610), *The Crucifixion of Saint Andrew*, 1606–7. Oil on canvas, 202.5 × 152.7 cm (79 3/4 × 60 1/8 in.). (a) Radiograph. (b) Handmade drawing of the pattern. (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a) Cleveland Museum of Art, (b and c) Lab O, (d) Lab O / João Mariano

47

A System to Keep Paintings on Canvas at a Constant Tension during Conservation Treatment

Luigi Orata, Painting Restorer, private practice, Florence, and Professor of Structural Conservation Treatment, Academies of Fine Arts, Bologna; Brera, Milan; and Naples

This paper focuses on the issue of tension variation on canvas paintings during conservation treatment. The solution proposed has been developed through the observation of several cases encountered during many years of professional activity. It aims at keeping the painting in a constant tension during structural conservation phases, thus minimizing potential damage to the canvas.

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INTRODUCTION

When a painting on canvas is removed from its stretcher, it usually undergoes a tension variation. In most cases, it will be restretched, using added tacking edges, on a temporary stretcher for structural treatment (e.g., consolidation of the paint and ground layers or for lining). During this operation, the painting is put under tension and stretched. When the work is finished, the canvas is detached again (another contraction) to be definitively stretched on the final stretcher (another stretching). These repeated movements cause mechanical stresses in the painting that affect its different layers, that is, the canvas as well as ground and paint layers, and these can result in real structural microtraumas.

The problem has previously been highlighted, for instance, by V. R. Mehra and Sergio Taiti.[1] Both restorers, despite coming from different restoration traditions and schools of thought, dedicated particular attention to the study of a method for maintaining constant tension during the treatment of a painting, specifically so as to avoid problems created by relaxation and contraction of the canvas. Mehra set up a well-known system with three stretchers in which, after the painting is removed from its stretcher, it is immediately tensioned on an interim stretcher by means of a nonwoven fabric. After the consolidation phase (or after lining, in the final phase), the system obtained is dismantled and the painting is remounted on the definitive stretcher. A possible solution, shared during his lessons, consisted of remounting the painting from the interim stretcher to a larger, definitive stretcher. The latter is positioned on the back, and the canvas is secured directly from the front, along the original edges, with metal staples. Naturally, Mehra was aware that this practice was not always feasible, especially in the presence of an original stretcher or dimensional restrictions (e.g., due to a frame or reinstallation in an architectural niche).

In parallel, Taiti, well aware of the stresses and movements occurring in a painting undergoing consolidation with animal glue in an aqueous solution (following the traditional techniques of Florentine glue-paste lining), figured out how to mount the painting on a larger interim stretcher. He employed strips of kraft paper, later replaced by polyester canvas as the use of different materials evolved, and thus maintained tension until the eventual lining. He was also developing ideas on the final step, although, unfortunately, these were never brought to fruition due to his premature death.

The sensitivity of approach demonstrated by these two important figures for numerous aspects of restoration was greatly influential as it spurred the desire to continue delving into what is a delicate and often undervalued subject.

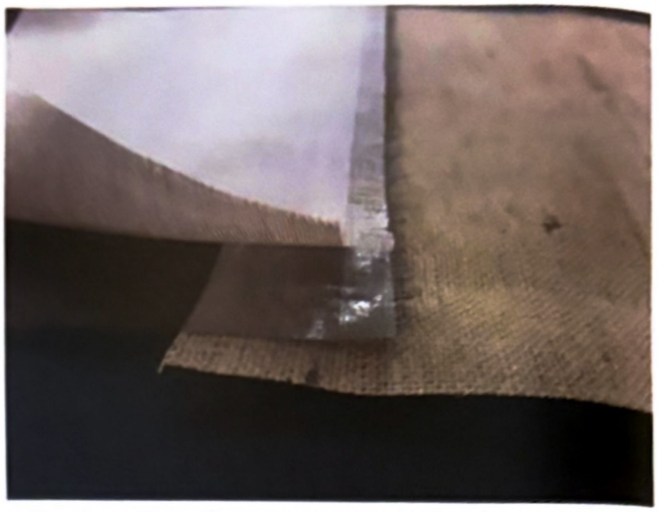

Figure 47.1 Detail of the double-strip lining used in the tension variation system for canvas paintings. From the bottom: original canvas, frayed Origam, Beva 371 film, and frayed Trevira, positioned in a staggered manner. Image: Luigi Orata

A VERSATILE SYSTEM

My experience in the field of structural conservation of canvas paintings has allowed me to test and use a system[2] to mitigate the problem of variation in tension of canvases undergoing restoration, with significant results. This innovation aims to maintain the painting under a constant tension during all of the phases of treatment and to transfer the degree of tension that is initially established for the temporary stretcher to the definitive one, thereby avoiding the potentially damaging "accordion" effect.

The system is extremely versatile in that it is applicable to paintings undergoing either only consolidation or a full lining, and hinges on the use of specially designed perimeter strips. Each strip is composed of two polyester canvas layers: the first, a lightweight polyester that comes in contact with the original painting (Origam 254, 18 g/m^2), and the second, a heavier polyester (Trevira C.S. Ispra, 130 g/m^2). Each is frayed[3] for about 10 mm along the longer edge. The individual strips, thus prepared, are then paired in a staggered manner, longitudinally, with Beva 371 film between them. They are then inserted in a vacuum envelope, and the adhesive is reactivated by heating it to 80°C, a measure aimed at ensuring a particularly solid bond[4] (fig. 47.1).

Once the painting is detached from the original stretcher, and after the back has been cleaned, it is possible to apply these double strips to the back of the original canvas (inside the fold-over marks from the original stretcher at a distance suited to the specific painting) with pressure (best if generated with vacuum suction for a better and more even bond) and heat, but only up to the minimal temperature for Beva reactivation (65°C), to provide for better reversibility. This means the double strip adheres to the original canvas less aggressively, while the bond between the two strips is stronger.

Afterward, the original canvas is stretched on the temporary stretcher using the plane of the table to provide support for the canvas as the double-layer perimeter strips are secured to the temporary stretcher (fig. 47.2). Following structural conservation treatment, the temporary stretcher and canvas are again laid facedown on a flat surface. The definitive stretcher is then positioned on the back, within the width of the temporary stretcher, aligned with the fold-over marks on the original canvas. The first of the two layers of the added tacking margin (the heavier, outside one) is cut free from the temporary stretcher and fixed to the definitive one with steel staples, thus preventing the canvas from contracting (figs. 47.3, 47.4). Only after having secured the entire perimeter is the second layer of the strip cut free from the working stretcher and fixed to the definitive one (fig. 47.5).

This sequence avoids variations in tension as, during the shift to the final stretcher, a bond is always maintained with the temporary stretcher. The initial tension is constant and can be transferred to the definitive stretcher.

For further study, the system could be tested on different models while carrying out measurements in order to give some scientific weight to the method described. This would provide numerical values and objective data to support the use of this simple technical innovation.

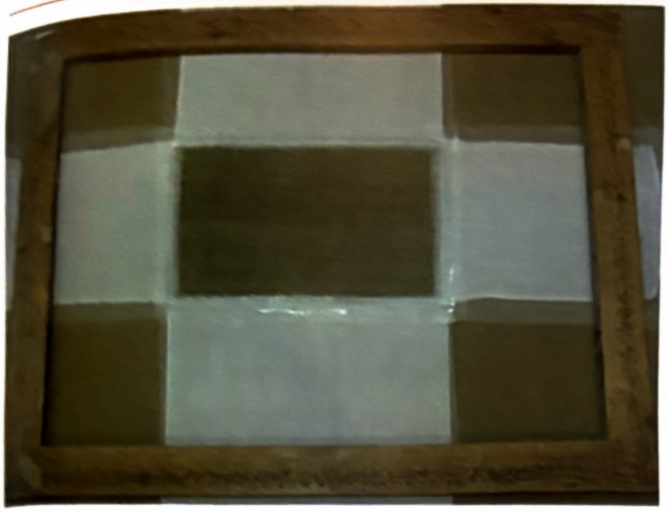

Figure 47.2 The double-strip lining is stretched and secured on the temporary stretcher. Image: Luigi Orata

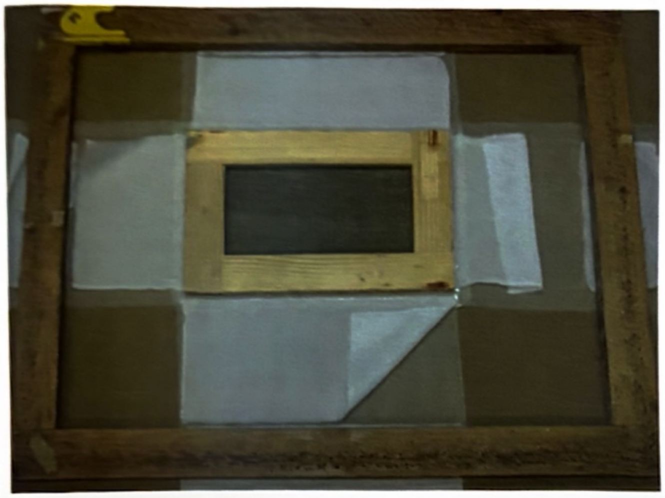

Figure 47.3 After structural conservation, the definitive stretcher is placed down. The first layer of the double-strip lining is cut free from the temporary lining and secured to the definitive stretcher while the second layer is still under tension. Image: Luigi Orata

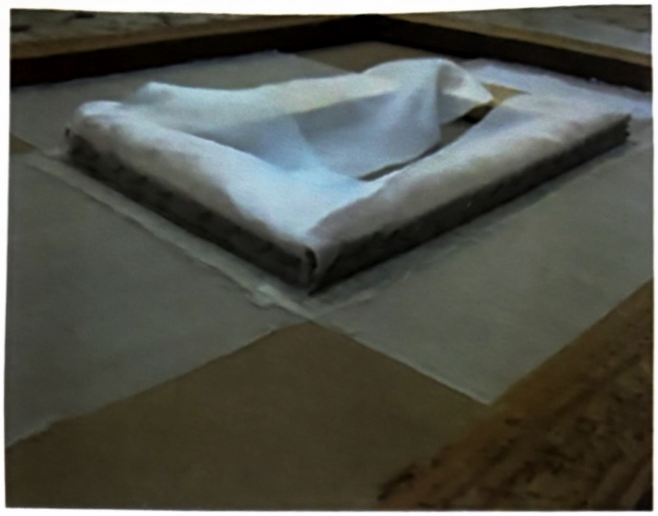

Figure 47.4 Detail showing attachment of the first layer to the definitive stretcher. Image: Luigi Orata

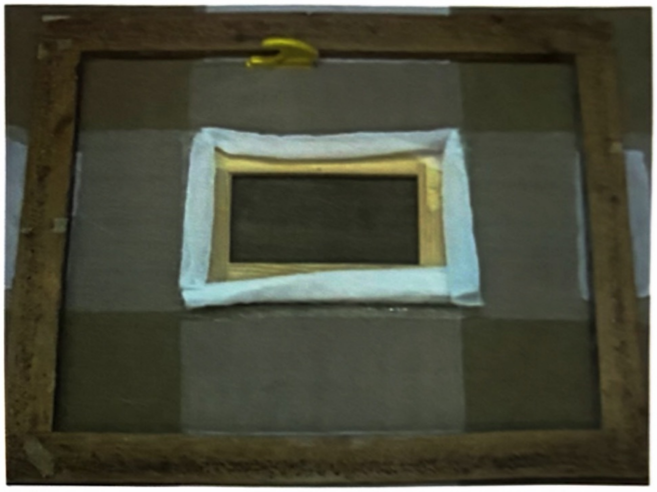

Figure 47.5 When the first layer of the double-strip lining is completely secured, the second layer is cut free and attached to the definitive stretcher. Image: Luigi Orata

NOTES

1. Sergio Taiti was head restorer of the structural conservation of canvas paintings at the Opificio delle Pietre Dure (OPD) from the 1940s to 1987, the year of his death.
2. The first use of this system was in 2002 on the painting that was the subject of my diploma thesis: Bartolomeo Bimbi, *Le zucche dei monaci di Monteoliveto*, 1714, oil on canvas, 202 × 144 cm.
3. The aim of the fraying is to lessen the abruptness of the differential created by the thermal-hygrometric exchange between the front and back of the original canvas.
4. Alternatively, different adhesives, canvases, or adhesion methods can be used, taking into consideration the adhesive strength that is optimal with respect to the characteristics of the painting.

62

Investigating Commercially Primed Contemporary Artist Canvases

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Lynn Chua, Conservation Scientist, Heritage Conservation Centre, National Heritage Board, Singapore
Filzah Mohd Amir, Assistant Conservator, Heritage Conservation Centre, National Heritage Board, Singapore
Ruby Awburn, Independent Conservator, Australia
Gillian Osmond, Paintings Conservator, Queensland Art Gallery | Gallery of Modern Art, Brisbane, Australia
Joey Ng, Lab Assistant, National University of Singapore

Contemporary painters often choose commercially primed canvases as their painting support; however, manufacturers provide little technical information about the materials used in their production. The authors were prompted to learn more about these materials' manufacture after observing unexpected responses to established conservation treatments. Canvas fiber, priming binder, pigments, and fillers used in fifty-three commercially primed canvases purchased from Australian and Singaporean suppliers were analyzed. The materials detected show variations in canvas types and priming formulations that suggest reasons for unusual conservation treatment characteristics.

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INTRODUCTION

Commercially primed artists canvases are common supports for contemporary painters. Such canvases are convenient and often affordable; however, the product information available for both artists and conservators to inform purchase choice or likely aging characteristics is limited. This paper reports on the material analysis of fifty-three commercially primed artists canvases purchased from Australian and Singaporean suppliers in 2018–19.

Research was prompted by observations that some contemporary paintings exhibit unusual responses to conservation treatment that are potentially attributable to their commercially primed canvas support. Observations include stretchiness, the priming's ability to tolerate heat above 45°C (sometimes as high as 80°C), unpredictable response to humidification, priming discoloration, and delamination of subsequently applied oil paint. Commercially primed canvases from seventeen applicable collection paintings dating from 1990 to 2018 were also analyzed; however, those results are presented here only where they help to inform the discussion.

BACKGROUND

Historical studies of commercially primed canvases document the frequent use of lead white, chalk, protein, and oil in single or double priming layers on cotton or linen canvas supports (Ravaud et al. 2014; Hackney 2020; Townsend et al. 2008). Today, these priming layers are commonly substituted with synthetic alternatives, with acrylics being the most commonly encountered. For example, Ormsby et al. studied priming layers of fifty-two paintings from the Tate collection dated 1963–2008 and identified 60% of priming layers as acrylic emulsion, 27% as oil based, and 10% as alkyd, with 3% "other" (Ormsby et al. 2008). The prevalence of synthetic fiber use in contemporary canvas supports is also a question to be investigated.

To inform canvas sample selection for this current study, thirty-seven Australian and Singaporean painters were surveyed about their canvas choices, revealing that most painters routinely purchased commercially primed canvases—selecting their canvas by trial and error, availability, working qualities, and price point (Osmond et al. 2018). Commercially primed canvases are usually produced as type U: universal (synthetic emulsion), suitable for both water- and oil-based paint; or type O: suitable for oil paint. However, many artists were unaware of the priming type and did not vary their canvas selection according to paint medium.

METHODOLOGY AND RESULTS

Fifty-three commercially primed artists canvases were collected from art stores in Australia and Singapore, representing nineteen brands manufactured in Europe, China, Australia, the United States, India, and Mexico: Artfix, Claessens, Belle Arti, Fredrix, Winsor and Newton, Caravaggio, Sydney Canvas Company, Art Spectrum, Clairefontaine, Mont Marte, National Art Materials, Jasart, Overjoyed, Pebeo, Semco, Francheville, Phoenix, Talens, and Colorpro. Samples cover various price points, and forty-nine samples were identified as having synthetic polymer priming and oil-based priming.

Canvas fiber, priming binder, and pigments/fillers were primarily analyzed using optical microscopy, attenuated total reflectance–Fourier transform infrared spectroscopy (ATR-FTIR), pyrolysis–gas chromatography–mass spectrometry (Py-GCMS), and X-ray fluorescence spectroscopy (XRF); some were analyzed with Raman spectroscopy and scanning electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDS). In addition, uniaxial tensile strength testing and heat testing were undertaken.

A summary of results is presented below. More detailed analysis for each sample is found as supplementary data (Carter et al. 2020).

Priming Stratigraphy

Cross sections were prepared, and four priming layer stratigraphies were identified in visible light. Thirty-two percent of samples contained single priming layers, often with irregular thickness. Others appeared as double layers in three stratigraphies: equal layer thickness, with the bottom layer sometimes irregular in thickness and usually opaque (30%); thin layer over thick, with the bottom layer often irregular in thickness (19%); thick layer over thin, with the bottom layer sometimes transparent or opaque and continuous or noncontinuous (19%). The multiple priming layers specified by suppliers were not always discernible.

BINDER

The top surface of priming layers was characterized using ATR-FTIR (table 62.1, fig. 62.1) (Osmond et al. 2018). At this surface layer, forty-nine of the fifty-three canvas samples contained synthetic polymer binders and four samples contained oil priming. Styrenated-acrylic predominated as a binder, followed by acrylic and acrylic–polyvinyl acetate (PVAc) binders. No alkyd binders were found.

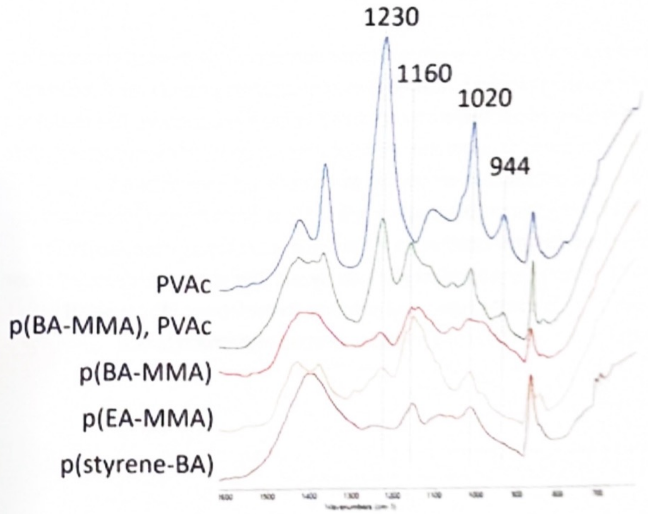

Figure 62.1 ATR-FTIR fingerprint region for priming highlighting key acrylic-PVAc peaks. Image: Queensland Art Gallery, Gallery of Modern Art, Australia, and Heritage Conservation Centre (National Heritage Board), Singapore

Table 62.1

Summary of results of analyses of 53 commercially primed canvases using ATR-FTIR and optical microscopy

Binder	%	Pigments and fillers	%	Fiber type	%	Weave	%
Acrylic-styrene	41.4	Chalk, titanium dioxide (TiO_2)	43.7	Cotton	58.5	Plain (1 × 1)	58.2
Acrylic	20.9	Chalk, TiO_2, talc	20	Linen	32	Half basket (1 × 2)	36.4
Acrylic-PVAc	11.3	Chalk	9.6	PET	5.7	Full basket (2 × 2)	5.4
Acrylic-PVAc-styrene	9.4	Chalk, TiO_2, barium sulfate ($BaSO_4$)	3.6	PET-cotton	3.8		
PVAc	7.5	Gypsum	3.6				
Oil	7.5	TiO_2, kaolinite	3.6				
PVAc-styrene	2.0	Other	15.9				

Py-GCMS provided further details of synthetic polymer binder constituents, including verification of the use of seven different acrylic monomers. Within the group of styrenated-acrylics, styrene n-butyl acrylate (BA) predominated (37%), and within the group of "pure" acrylics, only ethyl acrylate–methyl methacrylate (EA-MMA) and BA-MMA were found, with a slightly higher occurrence of EA-MMA. One EA-MMA priming showed significant amounts of diethylene glycol dibenzoate plasticizer. Within the group of PVAc-acrylic binders, some were copolymerized with vinyl versatate (VeoVa). Surfactants such as polyethylene oxide (PEO) (Scalarone and Chiantore 2004) were not observed with ATR-FTIR.

Priming layer combinations varied (fig. 62.2). Double priming layers included acrylic over styrenated acrylic (see fig. 62.2b), acrylic over acrylic-PVAc (see fig. 62.2c), and oil over styrenated acrylic (fig. 62.2d).

Variations were observed between ATR-FTIR and Py-GCMS data, including a significantly higher incidence of PVAc detected with Py-GCMS. This was found to correlate with the presence of PVAc in lower priming layers not captured by the surface-only ATR-FTIR. Thin surface layers were sometimes difficult to separate from other, similarly colored layers for Py-GCMS analysis (fig. 62.2d) (Osmond et al. 2018).

In total, thirty-four different copolymer binder combinations in the upper layer were found in the surface layer of the forty-nine synthetic-primed samples—indicating a wide variety of formulations and subsequent properties. The history of synthetic emulsion binders and copolymer properties is well documented, including in conservation literature (Scalarone and Chiantore 2004; Learner 2004; Croll 2007; Standeven 2011), which describes how copolymers are formulated to provide optimal coating properties. For example, adding monomers that have a higher glass transition temperature (Tg), such as styrene (or MMA), to a "soft" acrylic monomer such as n-butyl acrylate results in a stiffer and possibly more heat-tolerant priming, depending on the monomer ratio (table 62.2).

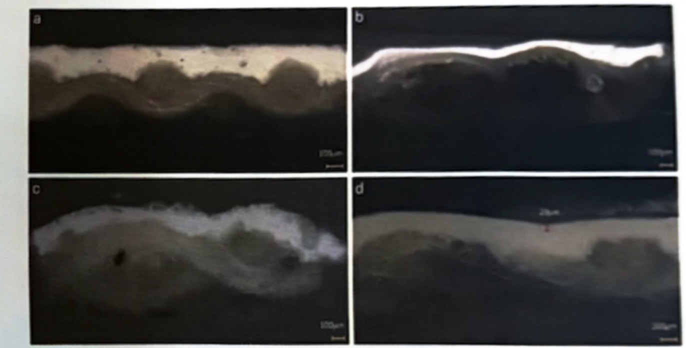

Figure 62.2 Cross sections viewed in visible light. (a) Artfix polyester canvas with single priming layer of PVAc (VeoVa)–acrylic (BA-MMA)–styrene with titanium white, chalk, and talc. (b) Caravaggio linen canvas with double priming layers; top: acrylic (EA-EHA-EMA-MMA) with titanium white (no chalk); bottom: styrenated acrylic (EA-MMA) with kaolinite. (c) Sydney Canvas Company cotton canvas with single priming layer of acrylic (BA-MMA)–PVAc with chalk and titanium white. (d) Phoenix cotton canvas with double priming layers. Surface: styrenated acrylic (ATR-FTIR). All: BA-MA-MMA-styrene-PVAc (Py-GCMS). Images: Queensland Art Gallery, Gallery of Modern Art, Australia, and Heritage Conservation Centre (National Heritage Board), Singapore

PIGMENTS AND FILLERS

Fourteen different pigment and filler combinations were identified. The most frequent combinations are detailed in table 62.1. Two-thirds of synthetic primings were

Table 62.2

Glass transition temperatures (Tg) of common monomers and copolymers used in coatings

"Soft" monomers	Tg (°C)	"Hard" monomers	Tg (°C)	Copolymers	Tg (°C)
n-Butyl acrylate (BA)	-43	Styrene (sty)	107	*p*(BA-sty) (20:80) (40:60) (60:40) (80:20)	 74 41 13 -16
Ethyl acrylate (EA)	-8	Methyl methacrylate (MMA)	105	*p*(EA-MMA) (20:80) (40:60) (60:40) (80:20)	 81 50 24 5

Source: Penzel, Rieger, and Schneider 1997

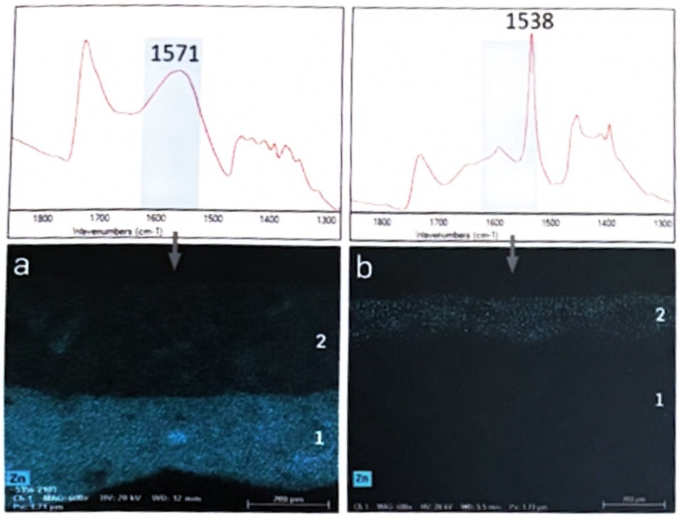

Figure 62.3 Cross-sectional SEM-EDX elemental distribution of zinc and corresponding ATR-FTIR spectra with highlighted metal carboxylate band from surfaces of (a) Claessens oil-primed linen, and (b) Artfix oil-primed linen. Images: Queensland Art Gallery, Gallery of Modern Art, Australia, and Heritage Conservation Centre (National Heritage Board), Singapore

composed of titanium dioxide and chalk; some also contained talc. Nine percent of samples contained chalk only. Pigmentation of layers also varied within samples; for example, titanium white was sometimes found only in the top of double-layered priming (see fig. 62.2b).

Oil Priming and Zinc Soaps

The four oil-primed samples were double primed. Three were oil over acrylic or acrylic-PVAc, and one contained two oil layers. Barium sulfate, titanium white, and calcium carbonate were found in oil primings. Additionally, zinc was detected in three of the oil-primed samples, and zinc soaps (amorphous and/or crystalline) were detected at the surface of these samples.

Amorphous zinc carboxylates (broad band centered 1571 cm^{-1}) were found at the top surface of the double oil priming where zinc oxide was present only in the underlayer. This suggests in situ formation of zinc soaps and migration from the lower layer to the surface (fig. 62.3a).

Crystalline zinc soaps (1538 cm^{-1}) were detected at the surface of two oil-primed canvases with acrylic-PVAc underlayers. The oil priming contained no zinc oxide, and thus zinc stearate was likely a constituent in the priming formulation (see fig. 62.3b). These results are important, as zinc soaps at the surface of oil-primed canvases may pose a risk to subsequent oil-paint adhesion (Osmond 2019).

CANVAS

Fiber analysis showed good correlation with the information provided by manufacturers. Cotton was the most prevalent fiber, followed by linen. Polyethylene terephthalate (PET) and PET-cotton blends were less common (see table 62.1).

Three weave patterns were identified: plain weave (1 × 1), half basket (2 × 1), and full basket (2 × 2) (see table 62.1). Cotton was typically found as half basket, while linen, PET, and PET-cotton blends were mostly plain weave. Twenty-five percent of cotton samples had a thread count of 10 × 30 threads/cm^2; otherwise, thread counts varied.

Uniaxial tensile strength testing of canvas samples indicated that the type or number of priming layers did not significantly affect tensile strength. The force at maximum for cotton and PET-cotton (56–258 N) was generally lower than for linen and PET (191–514 N) regardless of priming layers. The modulus of elasticity of the samples varied, generally showing a lower modulus of elasticity in the warp direction than the weft, aligning with research by others (Young and Jardine 2012).

HEAT TESTS

Response of the priming layer to heat was tested. Most samples were visually affected after holding a spatula heated to 80°C against the surface for one minute; however, there was no obvious visual effect in 19% of samples—that is, no flattening, burnishing, softening, or tackiness. No obvious correlation was found between heat response and binder or pigmentation type to inform conservation practice.

CONCLUSIONS

The synthetic emulsion primings found in this study reflect commercial development over the past seventy years. However, where industry has broadly transitioned from PVAc and PVAc-acrylic copolymers to acrylics and styrenated acrylics (Schwartz and Kossmann 1998), PVAc remains a common constituent in commercially primed artist canvases.

Styrene was found in 64% of priming surface layers—most frequently with acrylic but also combined with PVAc. Styrenated acrylics were also found as underlayers for both oil and acrylic layers. The prevalence of styrenated acrylics indicates a trend of increased use since 2008 (Ormsby et al. 2008).

Styrenated acrylic emulsions are generally used in more economical paints, as styrene monomers are cheaper than acrylics. However, styrenated acrylics can also produce high-end paints, depending on the performance required.[1] Importantly, styrene is not stable when exposed to UV radiation (Standeven 2011). It can become yellow and may "chalk" and crack if sufficient UV exposure occurs. When covered with another paint layer, styrenated acrylic is considered stable.[2] Thus, a general recommendation from this research is for artists to avoid leaving commercial priming layers (which may contain styrene) exposed to possible UV degradation.

In regard to oil-primed canvases, surface zinc carboxylates were identified. They present the risk of delamination of subsequently applied oil paint.

Of the fifty-three commercially primed canvases, none showed identical formulations of binder and pigment/filler except for some of the same brand. This finding implies that there is no standard formulation for commercially primed canvases, nor necessarily consistency within brands—the same product from different suppliers was not always identical, suggesting inconsistent production. Thus, priming-layer properties are difficult to identify from supplier information.

Cotton canvas predominated, primarily in half-basket weave. Synthetic canvases were not common; however, they showed the greatest tensile strength. Correlations between observations from artwork treatments and those works' commercially primed canvas type were unclear. However, within the small number of paintings analyzed (seventeen), artworks on half-basket weave cotton canvas with chalk-dominated priming were the main contenders for unusual treatment observations.

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EXPERIMENTAL EQUIPMENT AND CONDITIONS

ATR-FTIR: Thermo Scientific Nicolet iN10 microscope with DTGS room-temperature detector coupled to an iZ10 diamond ATR bench accessory; 16 scans over 4000–400 cm^{-1} range, 4 cm^{-1} resolution.

Py-GCMS: Shimadzu GCMS QP2020 combined with a Frontier PY3030D pyrolizer unit with autosampler AOC-20i. Pyrolysis conditions: 600°C for 0.2 minutes. Gas chromatography conditions: 40°C for 5 minutes, ramped to 300°C at 10°C/min., hold 5 minutes. Oil-containing samples were derivatized with 3 μl of 25% tetramethylammonium hydroxide (TMAH) in methanol. Mass spectrometry conditions: Electronic index (EI) mode (70 eV), scan range: 50–600 m/z.

Uniaxial testing: 500N Zwick/Roell with 10 mm sample width and gauge length, and speed of 100 mm/min. at 55 ±5% RH and 22 ±3°C. Samples were tested in warp and